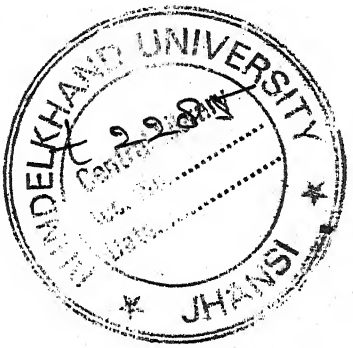
# PHYSIOLOGICAL ANALYSIS FOR BIOMASS PRODUCTION AND SEED YIELD IN STYLO

THESIS

SUBMITTED TO THE
BUNDELKHAND UNIVERSITY, JHANSI




FOR THE DEGREE OF
DOCTOR OF PHILOSOPHY
IN BOTANY

BY

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To,

The Vice Chancellor
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Sub: Submission of Ph. D.

Ref: BU/Adm/Res/2004/746-48 dated 29.10.04

Sir,

I am forwarding herewith, the thesis entitled "*Physiological Analysis for biomass Production and Seed Yield in Stylo*" by Mr. Raghvendra Kumar Tripathi for the degree of Doctor of Philosophy in Botany, Bundelkhand University, Jhansi. The work has been carried out at Indian Grassland and Fodder Research Institute, Jhansi under the supervision of Dr. R. K. Bhatt.

Thanking You

Yours Faithfully

**(P. S. Pathak)** 28/1

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# Supervisor's Certificate

This is to certify that this work entitled *"Physiological Analysis for biomass Production and Seed Yield in Stylo"*, is an original piece of research work done by Mr. Raghvendra Kumar Tripathi, M. Sc. (Botany) under my guidance for the degree of Doctor of Philosophy of Bundelkhand University, Jhansi (U. P.) India. I further certified that:

(i) The thesis has been duly completed

(ii) It embodies the original work of the candidate himself

(iii) The thesis fulfils the requirement for the Ph. D. Degree of University

(iv) No part of this thesis has been submitted for any other degree or diploma

(v) It is up to the required standard both in respect of its content and literary presentation for being referred to the examiners.

(vi) It is also certified that the candidate fulfils the requirements of attendance.

**(R. K Bhatt)**
Supervisor

# Declaration

I hereby declare that the thesis *entitled "Physiological Analysis for Biomass Production and Seed Yield in Stylo"* being submitted for the degree of Doctor of Philosophy of the Bundelkhand University, Jhansi (U. P.) India is an original work carried out by me and no part of this work has been submitted for any degree or any other academic qualifications at any other university.

**(Raghvendra Kumar Tripathi)**

# Acknowledgements

*With great pleasure and gratitude I express my indebtedness to my Supervisor, Dr. R. K. Bhatt, Senior Scientist, Seed Technology Division, Indian Grassland and Fodder Research Institute, Jhansi, India for his precious guidance, constant encouragement and constructive criticism in solving problems during the course of present investigation.*

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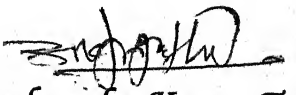
*Last but not least, I owe my special gratitude to my most loving grandfather, parents, whose affection and tremendous inspiration has boosted my interest under every circumstance and has helped in compiling this research work.*



**(Raghvendra Kumar Tripathi)**

# Contents

# 1
# Introduction

Large gap in requirement and availability of forage seeds is one of the major constraint in development of fodder resources in the country. With the increasing of live stock population in India it becomes imperative to produce more forage biomass to meet the demand. There exist a critical shortage of fodder i.e. to 80 million tonnes dry and 660 million tonnes green as reported by Hazra (1995). To over come this situation, there is need to increase fodder production by efficient utilization of all the land resources and technologies. The main reason so far observed from the various reports is low availability of forage seed. In an estimates the current demand of seeds of cultivated fodder is around 3,55,000 tonnes per annum which is based on the area under cultivation (8.3 m ha) and target replacement rate of 10% (Bhag Mal, 1996). Thus, it is evident that low priority is being given for fodder seed production by the major seed sectors. But the increase in availability of improved and high yielding varieties and their demand by the farmers' targets has been increased for the production of quality seeds.

It is estimated that our country is able to meet out only 30, 25 and 10 percent seed requirement of cultivated fodder, pasture forage and fodder trees. By

and large forage are shy seed yielder. One of the reasons might be due to genetic limitation of seed setting, non-synchronised flowering/ maturity, abscission causing flower, pod and seed drop and the physiological drift during grain development.

The nature of forage seed production is more complex and a number of environmental and physiological factors have a significant impact on seed production programme in forages. Moreover, the agroclimatic zones mainly affect seed production of some major fodder crops. In most forage species including forage legumes, many of the traits associated with high seed yield potential are negatively correlated with forage production. There are large numbers of morpho-physiological reasons for low seed yield as described by Misra and Bhatt (1995). As breeding programmes are aimed predominantly at selection for improved agronomic performance. Improved seed crop management systems can also be developed with increase seed yield potential and the promotion of the potential which is harvested. The development of simple techniques to assist the seed producers to determine the important stages of crop development i.e. peak flowering, optimal harvest date may also be required.

The goal of seed production system is to produce maximum yields of high quality seeds at lower input. The development of strategies to improve seed production requires an understanding of the biotic and abiotic factors limiting seed yield potential, the physiological basis of variation in seed yield and how current seed production practices fit into farming systems. This approach can have to determine a) the physiological constraints associated with seed yield development b) whether plant breeding and selection can be used to improve reproductive potential and seed production and c) the potential of improved management systems to increased seed yield. Strategies to enhance seed production systems can then be developed.

Large number of range grasses and range legumes have been worked out for their establishment in the grass legume mixture, range land condition, pasture

development, agronomical practices, nutritive value and their production potential under different sets of environments but still much remain to be worked out for their morph-physiological traits associated with the forage and seed yield.

The contribution of herbaceous legume in the vegetation is highly variable and fluctuates from place to place and season to season. The main role of legume is to improve fodder quality as pasture legume are rich in nitrogen and provide an extra source of protein for grazing animals, particularly during dry season when grasses are poorly nutritious. At the same time legume can contribute to the overall N economy of the pasture through nitrogen fixation, giving rise to an increased N content of the associated grasses. Finding and developing a legume suitable for grass legume mixture for tropical and sub-tropical pasture is still considered a challenge. However, during the recent past use of *Stylosanthes* species have gained importance as it gives larger yield of good quality protein rich fodder, easy in establishment in a variety of situations, its persistence, compatibility with dominant grasses in pasture under grazing condition and its good palatability. Therefore, stylos offer enormous possibilities for a sustainable production system and destined to play a special role in future agricultural development. Although, overall economics of stylo production system will depend on its yield in semi – arid condition, its effectiveness in maintaining soil fertility and its importance as a substitute for protein concentrate.

The genus stylo has been recognised for its adaptability and thus, has attracted many studies in different countries on its biology and utilization in the pastures. The genus *Stylosanthes* comprises to only 30 species but has provided more cultivars for tropical pasture than any other genus. The success of species within this genus may be related to their rather distinctive morphology and to wide inter specific variation in morphological and physiological characteristics (Burt *et. al.*, 1980). *Stylosanthes* have shown promise as a fodder, in agroforestry, silvipasture and hortipastoral systems to provide additional forage, enrich soil nutrients and stabilise soil to arrest land degradation. *Stylosanthes*, have shown

promise as pasture and forage crops in the tropical and subtropical regions in Australia, Africa, South east Asia and India.

*Stylosanthes* is a genus of the sub tribe *Stylosanthirae*, tribe *Aeschynomeneae*, sub family *Papilionoideae* and family *Leguminaceae* (Polhill and Raven, 1981) with its natural distribution in tropical, subtropical and temperate regions of the Americas, in tropical Africa and South East Asia. *Stylosanthes* grows mostly in the zone $35^0$ North and South of the equator. *Stylosanthes* is largely a neotropical genus with various number of species and subspecies being currently recognised (Mohlenbrock, 1958, 1960, Mannetje 1977, Ferreira and Costa, 1979). A lot of studies have been conducted abroad on its biology. In India research on this legume is meagre although *S. mucronata* grows naturally in the Dharwad region of Karnataka state. Other species viz. *S. guianensis, S. humilis, S. hamata* and *S. scabra* have been introduced in India in the late sixties. *Stylosanthes* have species and varieties suitable for different climatic and edaphic situation and grass association (Burt *et. al.*, 1980). Although *S. humilis* and *S. guianensis* were known previously to be valuable forage legumes (Anon, 1952, Singh and Chattergee 1968, Singh *et. al.*, 1968). There was little progress beyond the nursery and small plot stage until the late 1970s. The use of stylo to improve native pasture and animal production in drought prone areas is a recent and novel experience for India.

*Stylosanthes*, introduced in late sixties in India, have gained a prominent status in rangeland development programme. It is also extensively utilized in pastoral, agropastoral and silvipastoral systems for animal production. Due to its ability to restore soil fertility, improve soil physical properties and provide permanent cover, it is playing a vital role in the development of wasteland in the country. For Indian conditions five species viz. *S, guanensis, S. hamata, S. humilis, S. scabra and S. viscosaa* have been found most suitable (Ramesh, 1997). Out of these species *S. hamata* has been found most desirable and adaptive to wide ecological amplitude. It can be seen growing under partial inundation, sodic soils

with pH as high as 10.5, calcareous wasteland and revinous areas subject to high degree of erosion (Rai and Pathak, 1985).

The systematic work on various aspect's of the important pasture species of *Stylosanthes* done in India appears to be limited, though this pasture legume is reported to be common in wild form in southern region of the country (Trimen, 1974). It is generally recognized (Gardener, 1984) that *Stylosanthes* species, are adapted to highly infertile soils, after resisting heavy grazing and water stress. Many species of *Stylosanthes* have been evaluated at different sites in India. The first record of *Stylosanthes* was introduced for the first time in 1945 (Whyte, 1957). For the past so many years *S. guianensis* and *S. humilis* established in the 1960s on the soils of Ranchi, altitude 625m, and in the alluvial soil at Kalyani, altitude 9075 m, both at 23 N with 1300-1500 mm annual rainfall, showed that these species are to produce potential herbage yield of 7-10 t/ha (Mukerji and Prasad, 1960, Singh and Chatterji, 1968, Singh *et. al.*, 1968, Chatteerji *et. al.*, 1985). These species grew well with perennial grasses; *Pennisetum purpureum, P. polystachyon, Chloris gayana* (Prasad, 1980) and the annual *P. pedicellatum*.

In the initial stages, *S. humilis* was the predominant introduced material from Australia, but subsequently, this species became heavily infested with anthracnose. This coupled with low productivity and poor persistence under intense grazing pressure, eliminated the species from grazing lands. With the introduction of *S. hamata* and *S. scabra* from Australia and South America, interest in stylo again developed in India for the improvement of degraded grasslands and wastelands. Several varieties of these species were tested in experimental fields. At present, about 75% of the stylo area in India is planted to *S. hamata*, 20% to *S. scabra* and 5% to *S. guianensis*. *S. hamata* is grown mostly in the rainfall ranges of 600 - 1100 mm. *S. scabra* for 300 - 600 mm and *S. guianensis* for 1100 mm and above. *S. hamata* and *S. scabra* have been adopted widely for degraded soils and also used to a great extent for soils and water conservation problems. Both species are profuse seed producers, especially in the southern plateau region, with seed

yield ranges of 0.7 - 1.2 t/ha. With 1-2 irrigations, seed yields increase to 1.6-2.0 t/ha. in north and central India. However, seed yields are limited to 0.2-0.4 t/ha.

The Indian Grassland and Fodder Research Institute at Jhansi started working on evaluation of *Stylosanthes* germplasm in 1974 using accessions of *S. humilis S. guianensis, S. sundaica and S. mucronata.* of these, only *S. humilis and S. guianensis* were found to be promising (Magoon *et. al.*, 1974). Selections such as IGFRI-S-414 and IGFRI-S-2248 of *S. humilis* were distributed widely for their high green forage yield. There has been a strong research effort at the IGFRI on many aspects of *Stylosanthes* adaptation, germplasm evaluation, animal production, and pathology utilization under various agroclimatic and production systems. Recently one more promising species of stylo i.e. *Stylosanthes seabrana* was also introduced from Australia in 2000 (Pathak *et. al.*, 2005).

In the beginning, 4 species, *S. hamata* cv. Verano, *S. humilis*, *S. guianensis* cv. Schofield and *S. viscosa*, were evaluated for seed production. *S. humilis* was found highly susceptible to anthracnose. Gradually, *S. hamata* and *S. scabra* became popular and the rest were discontinued.

Species of *Stylosanthes* have been extensively used as a fodder, in agroforestry and silvipasture systems to provide forage, soil nutrients and stabilises land degradation. A major strength is the substantial seed industry, which currently produces-over-1000-tonnes of seed per years. Excellent agronomic performance in a range of soil types, and tolerance to acid and infertile soils make *Stylosanthes* adapted to a range of agro-ecological regions. *Stylosanthes* cv. seca, Fitzroy and Verano have been most popular and the sown area under *Stylosanthes* is increasing steadily. A managed and well controlled access to grazing and fodder having in areas restored with *Stylosanthes* will allow sustainable utilization of this legume to restore fertility, productivity and sustainability of the marginal lands. Inter cropping with cereals and plantation crops, ley farming to add 80-100 kg N to the soil, and agroforestry systems are among the other significant areas of potential

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utilization of *Stylosanthes* in India. The role of *Stylosanthes* in the different production systems has been outlined earlier by Edye (1984), among others.

Due to its strategic location (15 °27 'N, 75° 5' E) and proximilty to the major *Stylosanthes* seed production areas, IGFRI research station at Dharwad has been a major centre for seed production research and research on pests and diseases of *Stylosanthes* in recent years. Research is being carried out on *S. hamata, S. scabra, S. guianensis* and *S. viscosa* for fodder and seed yield as well as on native *S. fruticosa* populations.

Currently, the *Stylosanthes* seed industry accounts for a turnover of more than Rs. 309 M ($1.1 million) annually. Seed yield ranges from 0.4 - 0.5 t/ha in the first year and 0.8 - 1.1 t/ha during subsequent years depending on management practices. Based on 2 areas in Karnataka and Andhra Pradesh, benefit-cost ratios between 1.72-3.07 have been reported (Singh, *et. al.*, 1995).

Some of the major constraints, which may potentially impact on the seed industry include: (a) lack of private sector involvement - being government organisations, the major buyers are subject to changes in policy. A strong commercial interest and commitment from the private sector in the utilization of *Stylosanthes* is needed to ensure a secure future for the industry: (b) a labors - intensive production system - this often results in inconsistent quality and production; (c) only limited land available for seed production as more importance is given to commercial food crops; (d) only a limited range of cultivars grown; and (e) some of the cultivars have shown a high degree of susceptibility to anthracnose in other countries. There is an urgent need to improve the knowledge and understanding of disease and pest threats to the industry.

*Stylosanthes* has the potential to become the dominant forage legume in improving soil fertility, in restoring degraded lands through biological nitrogen fixation and in providing a feed base for livestock production. *Stylosanthes* is already a component of silvipastoral systems involving social forestry in villages in

Karnataka, among others. New *Stylosanthes* germplasum could increase this range of utilisation to more marginal areas. Obviously, the *Stylosanthes* seed production and multiplication will play a major role in any future expansion of *Stylosanthes* utilisation schemes.

Use of *Stylosanthes* species in tropics is gaining importance not only for animal feeding but also as a substitute for costly nitrogenous fertilisers. Stylos also offer possibilities for the improvement of soils and conservation of natural resources. Ruminants largely depend upon grazing lands not suitable for crop production and a sustainable stylo based production system with high protein and soil enriching properties is destined to play a special role in future agricultural development. Overall economics of stylo production system will depend on its yield in semi – arid condition, its effectiveness in maintaining soil fertility and its importance as a substitute for protein concentrate. The project aims to formulate technology for its adoption for a range of clients.

*Stylosanthes* sps. are dual purpose crop. In addition to seed, the fodder component plays an important role in the farming system. Crop residues are available after harvest in February/March when the lean period is at its most intense. Farmers highly favour the feeding of Stylo residues for the beneficial effect on milk yields. The seed husks are grazed by sheep and goats.

Due to narrow genetic base of *Stylosanthes* cultivars currently being used in India for the various utilization schemes there is a wider scope of introduction of different species and evaluation of in-bred materials. Evaluation of lines to select putative replaceable cultivars for use in different situations of the country where scabra /hamata or others are productive pasture components will finally improve the productivity and sustainability of pastoral, agropastoral and silvipastoral systems.

Stylo has assumed a very important position as a pasture legume for grasslands and also for degraded forest areas and wastelands in recent years. This

is virtually the only legume available for such purposes. Germplasm augmentation for different habitats and production situations, control of anthracnose through resistance breeding and regional testing are some of the major research priorities for this genus.

Foliar fertilization is gaining importance whenever nutrients uptake throughout the plant root is restricted. The restriction may be either plant or soil limitation. It may be feasible in case where plants well supplied with nutrients from soil source reach a stage where a supply through root can not meet the demand of crops. This phenomenon occurs prominently in legumes crops – a low efficiency of photosynthetic production per unit of N. when plants possess transition phase of flowering, the activity of roots declined rapidly and acts as barrier to absorb nutrients. For eg, photosynthate formed appeared to be directly used by flower and seed growth rather then its downward movement and thus resulting in decay of nodulation (Sinha, 1974).

Foliar spray of nutrients have been found to be beneficial because they are readily absorbed, cheaper to procure and not lost the root fixation, erosion and leaching (Bould and Hewitt, 1963). Foliar application of nutrients reduces the loss through absorption, leaching and other processes associated with soil application (Vasilas *et. al.,* 1980). Subramanian and Palaniappan (1981) reported foliar spray of nitrogen and phosphorus as good as soil application.

Significance of foliar nutrition was reported by several workers. Lewis 1936 (Borodulena and Runov, 1956, Wittwer and Teubner, 1959, Boynton, 1954). The usefulness of foliar application of nutrient depends on a) the existence of special problems that may not cope up well with application of fertiliser to the soil or by soil management, b) economical materials and methods of application. Optimum use of mineral nutrients as a foliar spray may be helpful for increasing the seed yield in Stylo crop. Plant hormone and inorganic nutrients share common physiological functions e.g., both of these growth factors influence the growth and development of plants. Therefore, application of nutrients, growth retardant and

growth hormone in sufficient quantities not only increases yield but also improve quality of produce and Stylo is no exception.

*Stylosanthes* research and development in India is at a very exciting stage. The versatility and usefulness of this legume in a range of production and agro-ecological systems has made it very attractive to government and non-government organizations alike. Its role in the various utilisation schemes for production and conservation has already been established. There is a large investment in the seed industry. Future research and development activities must target its utilization by the commercial and private sectors. Research should also help protect this investment by responding to threats from diseases and pests through the development and deployment of more resistant and well adapted cultivators.

During the recent past use of *Stylosanthes* species have gained importance as it gives larger yield of good quality protein rich fodder, easy in establishment in a variety of situations, its persistence, compatibility with dominant grasses in pasture under grazing condition and its good palatability.

Recently large number of genotypes of *Stylosanthes* belonging to *S. hamata, S. scabra, S. Viscosa* and *S. seabrana* has been introduced from Australia. These genotypes were never studied for their growth behaviour, biomass production and seed yield potential in semi arid regions of India. Therefore, one of the main piece of research work that has been carried out in this programme is the investigation of growth, biomass and seed production potential of different species/genotypes of *Stylosanthes* in semi-arid environmental condition and also the influence of growth hormones and nutrients on growth behaviour, physiological characters and seed production in *Stylosanthes hamata.*

# 2

# Review and Literature

## Biodiversity in *Stylosanthes*

The diversity of different *Stylosanthes* species has been characterised through GIS mapping approaches (Jones 1996, Jones and Sawkins, 1997, Sawkins 1999, Sawkins *et. al.,* 1999) using germplasm accessions that are considered to adequately represent the known distribution of major species (schultze- Kraft and Keller- Grein, 1994). The plotted collection points fell well inside the known distribution areas of *S. humilis* (Williams *et. al.,* 184), while some high probability areas indicated that there may be important as yet uncollected areas of *S. humilis* in western Brazil, adjacent to Bolivia, and in Venezuela, Nicaragua and Mexico. Interstingly, recent studies by Gama Lopez (2002) and collaborators have confirmed new *S. humilis* diversity from Mexico (Vander Stappen *et. al.*, 2000), which they regard as a major centre of *Stylosanthes* diversity; in addition, other new species have recently been identified from Mexico (eg Costa and Van den Berg, 2001, Gama Lopez *et. al.,* 2001, Vander Stappen and Gama Lopez, 2002), and some previously described doubtful taxa (Mannetje 1984), such as *S.*

*dissitiflora* and *S. subsericea*, appear too have been validated by this research (Gama Lopez, 2001).

Recently two ecogeographic surveys have been undertaken on *Stylosanthes*. Tsering (1996) surveyed herbarium specimens to identify and prioritise areas for further collection and conservation, emphasizing nine species. Sawkins (1999) studied four species using GIS and showed that *S. guianensis* has the widest geographic distribution, as compared to *S. viscosa*, *S. humilis* and *S. capitata*. *Stylosanthes guianensis* occurred in the widest range of vegetation, classified using FAO (1974) or the Holdridge system, from savanna to thorn scrub, tropical forest, dry forest and mountain tropical forest, dry forest and mountain tropical forest adapted to cool temperatures. Overlaying maps of conservation reserves on maps of the species' geographical distribution by point collection provided useful datasets for the identification and design of potential in situ reserves.

Due to different materials studied by Vander Stappen *et. al.*, (2000), Sawkins *et. al.*, (2001) examined the genetic variation in a collection of accessions *S. humilis* and *S. viscosa* but that geographical patterns of variation were generally similar between the two species. Without exception, they also confirmed the regional types of *S. humilis* postulated by Stace (unpublished b). Vander Stappen *et. al.*, (2000) investigated the diversity of Mexican accessions of *S. humilis* and contrasted this to the diversity observed in few accessions collected from South America. Due to the different materials studied by Vander Stappen *et. al.*, (2000) and Sawkins *et. al.*, (2001), it could not be established with certainty whether the apparent probable third gene pool from Central America and Venezuela was closer to the Mexican or the Brazilian gene pool. 'Twnsville *Stylo*', widely distributed in Australia and transferred to African countries and Florida, was closely related to the southern Brazilian genotype, while Philippion *S. humilis* showed isozyme patterns of the Venezuelan genotype (Stace, unpublished b). Finally, none of these studies detected relations of commercial plants with the Mexican gene pool.

In addition, *S. hemihamata cv. Verano* came from Venezuela, and the then promising *S. scabra* introductions from northeastern Brazil (Burt *et. al.*, 1979), which led to emphasis on collections from these regions.

## Taxonomy and Phylogeny

Mannetje (1984) reviewed the history of the genus *Stylosanthes*, which was established by Swartz in 1788 and later critically revised by Vogel in 1838, Taubert in 1891 and Mohlenbrock in 1958 and 1963. An increase in species described from 6 in 1800 to 1984 was followed by a relative stability of numbers until the 1990s. However, the validity of several species has been debated since this time and different views about the taxonomic treatment at specific and infraspecific levels have persisted. The International Legume Database and Information System (ILDIS 2001) registered a total of 42 valid species (31 accepted and 11 provisional) in addition to one misapplied species name and 43 synonyms. Since the last review (Mannetje 1984), new species have been described from Brazil – *S. nunoi* (Brandao 1991) and *S. longicarpa* (Brabdao and Costa 1992)- and more recently from Guerrer, Mexico- *S. salina* (Costa and van den Berg 2001)- all belonging to sect. *Stylosanthes*. From the so- called 'Catinga *Stylo*' (*S. seabrana*), cultivars 'Primar' and 'Unica' were registered in Australia in 1996 (Anon, 1996), even before this particular species of *Stylosanthes* sect. *Stylosanthes* had actually been validated by Mass and Mannetje (2002).

Classical taxonomic treatments *Stylosanthes* have been mainly based on some aspects of the floral and fruit morphology (Mannetje, 1984). In 1838 Vogal established the main division of the genus into the sections *Stylosanthes* and *Stylosanthes* (formerly Eu *Stylosanthes*), based on the presence of a rudimentary secondary floral axis and two inner bracteoles in the former and no such axis and only one inner bracteole in the latter (Kikbride and de Kirkbride, 1985, Mannetji, 1984).

The genus *Stylosanthes* has a monophyletic origin (Gillies and Abbtt, 1994, Vander Stappen, de Laet, 2002) and is closely realated to Arachis (Lavub *et. al.*, 2001), with the *S. guianensis* species complex as the most ancient group, clearly distinct from the rest of the genus.

Liu *et. al.*, (1999) identified ten basal genomes, named A to J . Genome A1 appears to be the maternal donor to all tetraploid species with a known AABB genome (*S. scabra*, *S. sericeicepts*, *S. tuberculata*), while genome C is the maternal donor for all those with a known AACC genome (*S. hamata* (4n), *S. subsericea*, *S. sundaica*). The limited variation between the taxa within each group raises the question as to whether they should be treated as different species (Liu and Musial, 2001). On the other hand, as more than one species have the same ancestral genomes, it seems most likely that more than one hybridization events has taken place (Vander Stappen, de Laet *et. al.*, 2002). This independent evolution of similar tetraploid combinations has been suggested by Stace and Cameron (1984) because of the disjunctions of the natural distribution of several *Stylosanthes* species. Only a few species are widely distributed, while many occur in restricted or isolated areas which appear to be local refuges, creating barriers to gene flow and thus allowing the evolution of regionally adapted genotypes (Stace and Cameron, 1984). A similar conclusion was reached by Liu (1997) using DNA markers to study intraspecific variation in *S. scabra.*

## Introduction of stylo in India

Over the past 45 years, many species of *Stylosanthes* have been introduced and evaluated at different sites in India. The first record of *Stylosanthes* introduction dates back to 1945 (Whyte, 1957). Trials in the 1960s on the soils of Ranchi, altitude 625m, and in the alluvial soil at Kalyani, altitude 9.75m, both 23°N with 1300-1500mm annual rainfall, showed that *S. guianensis* and *S. humilis* established well with potential herbage yield of 7-10 t/ha (Mukherji and Prasad, 1960; Singh and Chatterjee, 1968, Singh *et. al.*, 1968.

Since 1965, various species of *Stylosanthes* have been introduced from Australia, South America, Africa and the USA. The Indian Grassland and Fodder Research Institute (IGFRI) at Jhansi began evaluation of *Stylosanthes* germplasm in 1974 using accession of *S. humilis, S. guianensis, S. sundaica* and *S. mucronata* of these only *S. humilis* and *S. guianensis* were found to be promising (Magoon, *et. al.,* 1974). There has been a strong research effort at the IGFRI on many aspects of *Stylosanthes* adaptation, germplasm evaluation, animal production, pathology and utilization under various agro climatic and production systems.

*Stylo* was originally introduced to India for the improvement of grasslands in the early 1970s, but its real use commenced in the late 1980s. In the initial stages, *S. humilis* was the predominant introduced material from Australia, but subsequently, this species became heavily infested with anthracnose. This coupled with low productivity and poor persistence under intense grazing pressure, eliminated the species from grazing lands. With the introduction of *S. hamata* and *S. scabra* from Australia and South America, interest in *Stylo* again developed in India for the improvement of degraded grasslands and wastelands. Several varieties of these species were tested in experimental fields. At present, about 75% of the *Stylo* area in India is planted to *S. hamata*, 20% to *S. scabra* and 5% to *S. guianensis*. *S. hamata* is grown mostly in the rainfall ranges of 600 - 1100 mm. *S. scabra* for 300 - 600 mm and *S. guianensis* for 1100 mm and above *S. hamata* and *S. scabra* have been adopted widely for degraded soils and also used to a great extent for soils and water conservation problems. Both species are profuse seed producers, especially in the southern plateau region, with seed yield ranges of 0.7 - 1.2 t/ha. With 1-2 irrigations, seed yields increase to 1.6-2.0 t/ha. in north and central India. However, a seed yields are limited to 0.2-0.4 t/ha.

*Stylo* has assumed a very important position as a pasture legume for grasslands and also for degraded forest areas and wastelands in recent years. This is virtually the only legume available for such purposes. Germplasm augmentation for different habitats and production situations, control of anthracnose through

resistance breeding and regional testing are some of the major research priorities for this genus.

*Stylosanthes* as a genus (*Stylo*) has received the most attention worldwide as a tropical pasture legume and several cultivars have been released in a number of countries. The genus is well adapted to the topics and subtropics (Mass and Swakins (2004), Andrade *et. al.,* (1970) and is particularly suited to areas of law soil fertility with low P content and pH, although forms adapted to alkaline soil are available in the Caribbean, Central America and Maxico (Rai and Shanker, 1996). *Stylo* performs well under drought conditions (Patil and Pathak, 1986). In contrast to most other tropical pasture species, *Stylo* usually as a high N content combined with a very low P content. Although the amount of P is inadequate for the nutrition of grazing animals, other minerals seem to be available in sufficient amounts. In addition to improving natural rangeland and animal performance, *Stylo* are shown particular promise as a ley and cover crop in plantation agriculture (Niranjan, 1994).

In India in the past, mainly five species of Stylosanthes (*S. hamata, S. scabra, S. humilis, S. viscosa* and *S. guianensis*) has been introduced primarily from Australia and evaluated at different sites in India (Rai and Pathak, 1985, Sharma, 1985, Chaterjee *et. al.*, 1985, Rai and Patil, 1985, Ramesh *et. al.*, 1997). The native genotypes in India is *S. fruticosa* Alston which is widely distributed throughout the Southern peninsular regions (Hooker, 1879). Recently a new species namely *S. seabrana* was introduced in India.

Although several species of *Stylosanthes* have introduced to India over the years (Ramesh, 1997), so far Verano and a locally adapted *S. scabra*, possibly a derivative of the cultivar Fitzroy, are most widespread. In addition, several accessions of the newly described *S. seabrana* from Australia are rapidly expanding in peninsular India.

In India many different *S. scabra* species have been grown in agricultural systems as (a) pure legume pastures, (b) mixed legume/ grass pasture (c) mixed legume/cereal crops, (d) legume with rangeland, (e) legumes for seed production and (f) legumes in short fallows, agro forestry and silvipastures systems or cut-and-carry fodder grazing and cover crops. Details on the use of *Stylo* in India have recently been published by Ramesh *et. al.,* (1997). Only *S. hamata* Verano and *S. scabra* Fitzory and Seca continue to be cultivated, and seed of these cultivars is produced mainly by small holder farmers. Multi- location trials with new *Stylosanthes* species showed the potential of *S. seabrana* for a range of agro climatic zones. Smallholders in Hulkoti and Shurashettlykoppa near Dharwad have accepted this species for cut- and- carry fodder and leaf meal production. It has also been used to address environmental issues such as wasteland development, soil conservation, wildlife sanctuaries and reclamations of mining land especially of iron ore and mud slurry in the aluminum industry.

## *Stylosanthes* Species in Production Systems

*Stylosanthes* species are among the most important forage legumes across northern Australia (Gillard and Winter, 1984) and South America (Miles and Lascano, 1997, Thomas 1984), and they are playing an increasingly important role in Asia and India (Ramesh, 1997), China (Guodao, 1997) and more recently in Africa (Peters *et. al.,* 1994). *Stylo*s are now being used to feed many forms of livestock, including cattle, goats, sheep, pigs and poultry.

Across the tropics in Australia there are extensive areas of low fertility soils with a light textured surface, which are suitable for growing *Stylosanthes* species. *Stylosanthes guianensis* is the most suited species to the wet tropics; *S. hippocampoides* (cv. *Oxlely)* does well in the subcostal subtropics; and *S. hamata* have been successful species across the seasonally dry tropics (Miller, 1997). Recently, *S. seabrana* has proved adapted to heavy clay soils of the inland subtropics (Edye, 1997).

*Stylosanthes capitata* and *S. guianensis* were considered by Mannetje and Jones (1992) to be the best species for tropical and wetter areas of South- East Asia, and *S. hamata* and *S. scabra* were adapted to semi- arid areas. These species are all suitable for the cut- and- carry forage systems in this region (Phailkaew, *et. al.*,1984). Peters and Colleagues (2001) reviewed the role of improved forages in enhancing smallholder productivity and maintaining ecosystem health in the tropics and presented studies of forage adoption of *S. guianensis* in China. The high-yielding, cut and carry forage systems using *Stylosanthes* enhanced year round animal productivity, as well as improving land- use efficiency and reducing labour requirements.

In west Africa Muhr and Colleagues (2001) reported that cropping and dry season feeding strategies were increasingly being limited by land availability, so the agronomic performance of legueme species, in particular *S. guianensis*, promised substantial productivity gains once they could be integrated into the traditional fallow systems. Little and Agyemang (1992) have reviewed the role of *Stylo*santhes species in the African context and reported on its evaluation, population dynamics, animal production, agronomy, seed production and integration into cropping systems. Pengelly (2000) have summarized the success of *Stylo* in cropping systems of Africa and Australia.

Development of sustainable productions systems is a current objective of agriculture research and development in many countries including India (Paroda, 2001). Edye (1984) has reported the role of *Stylosanthes* in different production systems. Sustainability aims at maintaining production, the environment, economic gains and social equity in both temporal and spatial dimensions. This goal can only be attained when environmental production is balanced with social and economic sustainability. Achieving food and income security is a prerequisite for poor farmers, who are often unable to focus beyond their immediate survival needs, if they are to make decisions and investment affecting the sustainable use of natural resources. Balancing intensive sustainable use of natural resource management is likely to be the only way to reverse degradation, alleviate poverty and improve

food and income security of resource-poor farmers. Many forage species, in particular legumes, are multipurpose plants and desirable candidates for land management. They offer direct and indirect benefits to crop production including nitrogen enrichment of soils the suppression or reduction of weeds, insect pest and diseases addition of green manure improvement of fallow and use as cover crops and live barriers, among others. They reduce production costs by lowering the need for external inputs such as fertilizers and pesticides, and offer additional environmental benefits including reduced pesticide residues in crops, soil and water conservation of fossil energy and soil conditioning through nitrogen fixation. Improvements in soil fertility can support an increased intensification of agricultural production systems. The increased land use efficiency resulting from intensification can lead, in its turn, to protection of areas unsuitable for agricultural production by implementing policies which favor maximizing returns from labor and land rather than clearing new land for agriculture (Schultze- Kraft & Peters, 1997).

*Stylo* has a long history of research and development in India and has been used in many production systems, including as a fodder crop, in ley farming and intercropping, an agroforestry and silvipasture, and in wasteland development and soil conservation. These have been described in more detail by Ramesh (1997).

In India initially, *Stylosanthes* was introduced in drought prone areas to mitigate fodder shortage. Under these conditions, dry matter yields from 1-6 t/ha has been reported for *S. hamata and S. scabra* (Sreedevi, 1980, Rai and Pathak 1985). Under 1300-1500 mm rainfall in Ranchi and Kalyani in eastern India, yields of 7.5-10 t/ha have been obtained for *S. humilis* (Chatterji *et. al.*, 1985). In combination with range grasses like *Cenchrus ciliaris, Dichanthium annulatum* (Rai and Pathak, 1985), and *C. setigerus, Chloris, Panicum, Brachiaria, Urochloa* and *Heteropogon* (Das, 1984), *S. hamata and S. scabra* can improve productivity and nutritive value of herbage.

There is a significant amount of information on all aspects of *Stylo* research and development in India, largely based on work at experimental stations of government agencies such as the Indian Grassland and Fodder Research Institute and state Government department of Animal Husbandry (Ramesh *et. al.*, 1997). Recent developments in the commercial utilization of *Stylo* as a fodder crop have mostly been in the peninsular Indian states of Maharastra, Karnataka, Tamil Nadu, Andhra Pradesh and Kerala. These include a private farm in Tamil Nadu that has developed significant areas of *S. seabrana* to raise Mecheri goats and the excellent results from large-scale goat feeding trials with two *S. seabrana* and two *S. scabra* accessions used as cut-and-carry fodder at the Nimbkar Agricultural Research Institute near Pune in Maharastra. Near coimbatore in Tamil Nadu nearly 100 acres of *Stylo* pastures have been developed for sheep and goats by livestock owners on individual farms, 2-10 acres each. While sheep are allowed to graze, goats are stall-fed using cut-and-carry fodder comprising *Stylo*, *Brachiaria* and *Pennisetum* hybrids.

Introduction of *Stylosanthes hamata* with *C. ciliaris* and *D. annulatum* grasses in rainfed situations can produce quality forage and crude protein in the mixed stand is fertilized with 30 kg $P_2O_5$ /ha in pure *D. annulatum* (Rai 1986a) and *C. ciliaris* stands (1989). Growing *C. ciliaris* and *S. hamata* in alternate rows gives 29.3% higher dry forage yield and 67.2% higher crude protein yield over the grass alone (Singh, 1983).

## Stylo in silvipasture

There has been a resurgence in interest on *Stylo* as a multipurpose legume and renewed optimism at the grass root level for *Stylo* usage in plantation forestry. This is combined with enthusiasm for improvements in soil and water resources to increase forage, fuel and timber production, and to generate additional income for villagers. Consequently, active participation by villagers in the planning and development process and sharing of income has been key factors. This has been matched by a strong renewed interest from federal and state government

departments and in particular non- government organizations. At many sites there has been a spectacular transformation of arid and degraded landscapes. Salboni in West Bengal is one such spectacular example. The area has a red latertic acid (pH 5.4) soil with average fertility in a subtropical climate. Here 1800 of the total 2500 acres available have been planted to native tree species such as *Dalbergia* and introduced *Eucalyptus* with a healthy undergrowth of grass and legumes including *S. guianensis*, *S. scabra* and *S. hamata*. In this government sponsored scheme villagers received proportion of all produce from the land and have managed access to fuel wood and cut and carry fodder.

## Stylo in watershed and soil conservation

The biggest expansion in the use of *Stylo* in India has occurred in the development and stabilization of watershed and wastelands, mainly through government funded or initiated schemes. The program is now well established and has generated a tremendous interest among non-government organizations (NGOs) and farmer groups, who are now improving watersheds and developing wastelands using private resources.

In the past few years the biggest utilization of *Stylo* has been by the watershed/wasteland schemes, which are the largest buyers of commercially produced seed in India. In the past these developments were largely government funded and often did not last once the areas were opened for communal grazing. Recent developments include many partnerships between cooperatives of smallholder farmers and non-government organizations (NGOs).

Established in 1967, the Bharatiya Agro Industries Foundation (BAIF) is one of the oldest NGOs in India with a program covering a million families in 8000 villages. At one of its serviced villages 'Manjunathpura' a 70 ha area has been improved through water harvesting, agro forestry and mixed cropping in a region of 600 mm annual rainfall, mostly received within a few days, often over 100 mm/day. To encourage soil organic matter build-up, each property/land parcel

has been planted with a mixture of trees such as *Dalbergia latifolia, Sesbania sesban, Melia azedirachta, Calliandra calothyrsus, Eucalyptus camaldulensis, Gliricidia sepium* and *Leucaena leucocephala,* and shrubs such as *Acacia rugata, Agave sisalana, Agave vera-crluz, Caesalpinia crista, Erythrina suberose, Jatropha cascus* and *Parkinsonia odoratissimus* along its border, and with legumes including *Stylo* for soil enrichment. The 'Surashetty Kopa' cluster of villages in Karnataka is one of the best examples of *Stylo* significantly improving smallholder income and wellbeing through a BAIF-mediated participatory program. Started in 1998, these villages, covering only 42 acres of near barren land, have used *S. scabra, S. hamata* and more recently *S. seabrana* to improve soil fertility and provide income through seed sales. Some farmers in this area have intensified livestock production using forage crops including *Stylo* as the main feed resource, enabling them to cope better with droughts rather than relying solely on cropping.

Government funded initiatives have continued to improve large tracts of wasteland using *Stylo* as the pioneering species. A program of the Hyderabad Urban Development Authority (HUDA), spanning several thousand hectares near Hyderabad, has combined wasteland development with income generation for rural women from selling *Stylo* seeds. The women are paid as laborers for all farming operations and in turn sell *Stylo* seed to HUDA for further sowing in wastelands.

The use of *Stylosanthes* spp. (*Stylo*) has made a tremendous impact on the agricultural systems in India, especialy in improving natural grazing lands, rehabilitating degraded forests and community lands and rejuvenating rain fed crop and livestock production systems. It supports the livelihood of > 70% of the nomadic and rural population, where the livestock is dependent on these resources. Since 1968 the Indian Grassland and Fodder Research Institute has made a major contribution to *Stylo* research and development, including recent on-station and on-farm operational systems. *Stylo* used as a pioneering colonizer to stabilize degraded and problem soil and watersheds in extensive areas spanning most of the Indian states. Both government and non-government sectors have actively participated in this work, often following participatory approaches. The availability

of new and more suitable *Stylo* has generated a renewed enthusiasm for all such development programs were the rehabilitation of degraded sites is desired. Combining environmental remediation with the forage and commercial need of communities that rely on *Stylo* would assure a sustainable bright future for *Stylo*.

Wasteland development and soil conservation as a component of agroforestry and or silvipastoral system, *Stylo* plays a significant role in the stabilization and sustainable utilization of degraded lands. For instance, *S. hamata* is used with *C. ciliaris, C. setigerus* and *P. antidotale* in soil conservation and land stabilization in sand dunes in Haryana, and *S. guianensis* is used for stabilizing terraces in the foothills and valleys of Manipur (Gupta *et. al.,* 1989). Government organizations such the National Wasteland Development Board, Agriculture universities and NGOs have used *Stylo* to restore wastelands and develop them as forage, fuel wood, forest products and horticulture resources.

At least three species have the potential to be used in wasteland development. *S. fruticosa* is mainly districted in dry localities of orissa, Andhra Pradesh, Karnataka, Tamilnadu and Kerala at altitudes up to 900 m and on the costal areas. Tribal people used it for meditional purposes against diarrhea and cold. *S. guianensis* is distributed in high rain fall areas of Assam, West Bengal, Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, Karnataka, Andhra Pradesh, Tamilnadu, Andaman and Nikobar Islands, and some are adapted to acidic, saline-alkaline and waterlogged areas. Cultivars IGFRI S-4214 and IGFRI S-96-1 grow well in wet areas with para grass, Setaria, Rhodes guinea, Dinanath (*Pennisetum pedicellatum*) and thin Napier. *S. hamata* is by far the most widely used species in wasteland development in India since it is well adapted to infertile soil and can be grown on a wide range of soil types from shallow sandy clay-loam to heavy black cotton and red chalka soil. It is suitable for semi-arid tracts with around 425 mm annual rain fall. Other species including *S. humilis*, *S. scabra* and *S. seabrana* have more specialized niches in the targated environment. For instance *S. seabrana* is suited to heavy soils and *S. scabra* can be grown in areas with about 325 mm rainfall.

## Stylo as a nurse crop

The potential of *Stylo* for soil improvement through nitrogen fixation and carbon sequestration provides added nourishment to the associated vegetation (Pathak *et. al.*, 2004). In a study on degraded lands the tree growth of several multipurpose trees was improved when in association with *S. hamata.* This also produced sufficient nutritious forage for livestock. Such associations are exploited with increasing popularity in many systems including: (i) in the social forestry programs run by the state governments as a mandate *Stylo* is recommended and used to provide an effective ground cover and forage for the livestock ii) in the Telengana region of Andhra Pradesh, *S. hamata* sown in a *Leucaena leucocephala* plantation gives better yield (4.5 t/ha/year) and dry matter accumulation by *L. leucocephala* than with grasses like *C. ciliaris* (Neelam Seharan *et. al.,* 1989) iii) in West Bengal, fuel wood species such as *Eucalyptus* and *Acacia auriculiformis* perform well with sowings of *S. guianensis, S. scabra, S. hamata* and *S. humilis* (Lahiri, 1992); iv) in the acid soils, *Acacia auriculiformis* with *S. humilis* help to improve pasture yield and fuel wood production (Gill, 1992); and v) in forestry plantations of the eastern Himalayas, *S. hamata* in bamboo plantations and teak seed nurseries improve soil fertility (Singh *et. al.,* 1992).

In plantation and orchard crops such as *Psidum guajavae, Eugenia jambolana* and *Annona squamosa, Stylo* is used to suppress weeds, enrich soil and provide fodder (Dasthagir and Suresh, 1990). There are similar reports for custard apple and gooseberry (Phyllanthus emblica) (Gill and Gangawar, 1992); *Alnus nepalensis* and pineapple on hilly terrain of Meghalaya (Chauhan *et. al.,* 1993); coconut in Kerala (Pillai *et. al.,* 1995); and tea gardens in Kurseong (Macalpine, 1956).

## Intercropping with rainfed crops

In one IGFRI study productivity improved by 50% of the expected yield of the mixture when *Stylo* was grown with *Pannicum maximum* in different

proportion under rainfed condition (<800 mm rainfall) (Bhatt, 2003). Similar intercropping with other rainfed crops such as sorghum, pearl millet and maize has improved yield and quality of the cereal crops, improved fertility, and protected soil and nutrients loss (Singh *et. al.,* 1986). In one study soil nutritional status, physical and chemical characteristics changed for the better using *S. hamata* as an intercrop with sorghum or pearl millet (Hazra, 1997). Increase and soil fertility, especially available nitrogen, with *Stylo* used in a rotation with cereals has translated to increase cereal yield. In the fourth year of a rotation, the organic carbon (0.56%) and available N (144.7 kg/hac.) were optimum in treatments where *S. hamata* was grown continuously for three years followed by a sorghum – *S. hamata* –*S. hamata*-Sorghum rotation (0.35% organic carbon and 141.1 kg/hac available N) (Rai & Shanker, 1996, Singh and Singh 1987). Improvement of soil fertility can potentially extend the benefit beyond the immediate cropping season.

## Growth and Morphology

Light is one of the most important factor affecting growth, development and competition of plants as it is directly concerned with production of growth and biomass. Evans and Hughes (1969), Pandey and Sinha (1977), Corre (1983), Dale and Causton (1992) have investigated a wide verity of plants to understand the effect of light on their growth, productivity morph genesis and reproductive behaviors.

Naugraiya and Pathak (2001) reported that pasture grasses and legumes, viz., *Cenchrus ciliaris, Chrysopogon fulvus, Sehima nervosum* and *Stylosanthes hamata,* were cultivated with fodder tree species *Acacia tortilis* and *Leucaena leucocephala* under rainfed condition in semiarid climate. The structure of herbage community under tree canopy and open field was found directly related to the level of available climatic and edaphic features. Photosynthetically active radiations played important positive role to govern the level of density and dominance, which were in order to open field > *A. tortilis* > *L. leucocephala,* while the level of species diversity increased with decrease of dominance.

Growth analysis is being used as an important tool for assessing crop productivity in various crops (Watson 1952, Radford 1967 and Sestak *et. al.*, 1971).

The concentration of nutrients in the plant tissue is of great ecological significance. The availability of nutrients indirectly affects the pattern of nutrient distribution in the various components of a plant. Nitrogen is mostly required by grasses and legumes for enhanced biomass yield. As compared to grasses, legumes require relatively high phosphorus. Potassium plays significant role for crops grown in rain fed conditions. Some of the nutrients (N, P and K) have been reported to be associated with various physiological processes. Naidu and Swamy (1994) observed that concentration of N, P and K in several tropical tree species varied from month to month. The concentration of N, P and K are higher in the young leaves and decreased progressively with age (James and Smith, 1978; Ralhan and Singh, 1987; Verma and Mishra, 1989). Light intensities indirectly influence the nutritional uptake of plants up to some extent. The process of nitrogen metabolism is greatly affected unless the plant receives enough light for rapid photosynthesis. In the deficiency of light, nitrogen is not rapidly utilized which in term affects effective utilization of carbohydrates.

Crop productivity per unit area is a result of interactions of physiological processes of genotypes with environment. In most of the forage crops, significant advances are possible through the development of suitable plant types responsive to different conditions making them more efficient than others. Major advances in forage are possible only when improved plant types capable of harvesting more solar energy, faster photosynthesis, efficient translocation of photosynthesis to useful parts, high water and nutrient use efficiency, better growth and productivity under water stress situations and efficient utilization of plant growth regulators for promoting growth and yield.

Celso *et. al.*, 2004 reported considerable genetic variability among the germplasm of *Stylosanthes* studied for different characters

## Leaf Production

The growth of leaf may be divided into two stages, each affected differently by environment. In the first stage, when initiation and emergence of the lamina depends on the growth of the plant as a whole, an increase in light intensity or temperature leading to increased plant growth gave similar increases in the growth of developing leaves. The second stage occurs when the lamina grows out of the protecting sheaths of earlier leaves, becomes directly exposed to the light environment, and begins photosynthesis. The morphogenetic effects of light intensity, temperature and photoperiod during this period are not necessarily the same as a whole.

The dimension of the mature leaf lamina has also been found to be affected by increased light intensity and temperature (Kozlowski and Clausen, 1966). Leaf thickness is found to be increased with increasing light intensity. As the temperature increases the fresh and dry weight also increase. Pokhrial *et. al.*, (1989) have reported in *Populus deltoids* the maximum number of leaves per plant were observed in the month of April and minimum in July, whereas maximum number of leaves were shed in the month of November.

Lodhiyal *et. al.*, (1992) have reported that the contribution of leaves to above-ground biomass was 7.6-11.5%, which exceeds the higher side of the range, 2.6-9.3%, reported for certain temperate and tropical forages of World (Harada *et. al.*, 1972, Johnson and Risser, 1974, Whittaker, 1975, Singh, 1979, Negi *et. al.*, 1983, Rawat 1983, Rana *et. al.*, 1989) and 3.0-10.0% reported for *Populus deltoids* (Raizada and Srivastava, 1989).

The variation in leaf production and leaf expansion rates at comparable age, were more season dependent. Variation in specific leaf weight (SLW) was dependent more on growing season than on the age of the plants (Ledig *et. al.*, 1974), however the effect of age was more prominent on leaf weight ratio (LWR) than on leaf area ratio (LAR). The SLW is higher at lower temperature (Peet *et. al.*,

1977), and lower at higher temperature (Raper *et. al.,* 1971). Correlation between leaf area and yield (Alluwar and Deotale, 1991) suggested the importance of chlorophyll and leaf area.

Guenni, *et. al.*, (2000) reported that the rate of expansion and duration of growth of an individual leaflet was positively and negatively correlated with the mean temperature, respectively. The optimum temperature for leaf growth appeared to be close to 30°/20 °C. The temperature had minimum effects on the final leaf size. More pronounced effects of temperature were observed on the rate of leaf and branch production per plant after flowering; these parameters increased with temperature regimes. This effect varied, however, with genotype. Consequently, it is postulated that the ability to grow at sub-optimal temperatures may be related to the capacity of producing enough leaf area for photosynthesis. The expansion of leaf area per plant may be, in turn, promoted by flowering at these temperatures. At higher temperatures, the degree of leaf area expansion seemed to be more dependent on the accession's growth habit.

Bhatt *et. al.,* (1998) indicated that leaf area production was directly correlated with dry matter production. *S. hamata* and *M. atropurpureum* showed good association with grasses as indicated by dry matter production and leaf area during the third year of growth.

Nevertheless, information on physiological potential of the genotypes might be of much significance in the crop improvement programme (Freeman *et. al.*, 1993). The importance of physiological parameters such as leaf area, leaf area duration and net assimilation rate in crop productivity was emphasized by Watson (1952).

The genotypes IGFRI-3108 and 678 of *Cenchrus ciliaris* and IGFRI-76 and 7 of *C. setigerus* were selected for their high leaf area index and light utilization efficiency under semi arid region (Bhatt and Misra, 1990).

## Biomass production

May and Webber (1982) have reported that patterns of above ground standing crop, belowground biomass, and above: belowground ratios are controlled by water availability, length of growing season, exposure and soil stability. Sah *et. al.,* (1994) have reported that the canopy biomass and total biomass replacement was maximum during the rainy season, whereas, the replacement of the root biomass was greater during the winter.

Consistently in yield characteristics is an important feature desired by plant breeders. Studies on genotype environment interactions and stability of yield components assume significance as it can provide valuable information about adaptability of a cultivars to a particular region (Crossa 1990, Rafii, 2001) and help to identify the production constraints at different agro climatic regions. Environmental factors like rainfall, temperature, relative humidity, solar radiation and other soil factors, influences the plant growth and productivity.

Varietal differences in dry matter accumulation and its partitioning into reproductive parts were observed in cotton genotypes (Nagabhusan *et. al.,* 1993, Unruh and Silvertooth 1996). Hosmani, *et. al.,* 1998 reported that the green forage yield of *Stylosanthes* differed between years and was significantly higher in *S. hamata* than in *S. scabra.*

Biomass productivity traits were positively correlated with transpiration efficiency and negatively correlated with carbon isotope discrimination and specific leaf area, whereas transpiration was positively correlated with biomass productivity traits and negatively correlated with specific leaf area. Carbon isotope discrimination was significantly and negatively correlated with transpiration efficiency (Thumma, *et. al.*, 2001).

Hosmani *et. al.*, (1998) indicated that the production potential of mixed sward of *Stylosanthes* (*Stylosanthes hamata* and *S. scabra*) in simple mixtures with

8 forage grasses. The green forage yield of *Stylosanthes* differed between years and was significantly higher in *S. hamata* than in *S. scabra*. Among the range grasses *Brachiaria decumbens* and *Cenchrus ciliaris* gave the highest green forage yield in both years. Total green forage yield of mixed swards with *Stylosanthes* grown in association with *C. ciliaris* followed by *B. decumbens* was significantly higher than in these grasses grown alone. The dry fodder yield of mixed sward was significantly higher with *Panicum coloratum, C. ciliaris* and *B. decumbens* than with other grasses.

Maximum dry matter yield, leaf area index (LAI), crop growth rate (CGR) and light use efficiency (LUE) were observed in Tri specific hybrid (TSH) followed by *Pennisetum polystachyon, Panicum maximum, Cenchrus ciliaris and Chrysopogon fulvus* indicating their for potential for maximization of productivity under semi arid tropical environment. Significantly high positive relationship was found between DMY and LAI; CGR and LUE (Bhatt and Tiwari, 2004).

Marked differences have been reported in dry matter production, specific leaf weight and net assimilation rate in different genotypes of plant species and these characters can be used to identify the elite plant types (Murthy *et. al.*, 1986).

Tri specific hybrid produced higher green and dry matter yield (DMY) followed by *Pennisetum polystachyon, Panicum maximum, Cenchrus ciliaris* and *Setaria sphacelata* under high shading conditions i.e. 50% and 25% light intensities indicating their shade adaptation compared to other grass species tested. The higher accumulation of nitrogen in leaves and crud protein under moderate shading shows that these grasses are able to maintain their quality even under shading environment. The biomass production in term of DMY appears to be more closely related with the nutrient accumulation in leaves. Bhatt *et. al.*, 2002).

The physiological basis of genotypic differences in growth and biomass production amongst genotypes of grasses were reported by Bhatt and Misra (1990). In *Pennisetum pedicellatum* four promising genotypes were evaluated for their

biomass production and it was reported that maximum dry matter yield, crop growth rate, leaf area index, specific leaf weight and net assimilation rate were recorded in Bundel –1 followed by Bundel-2 (Bhatt *et. al.,* 1993). Amongst the ten genotypes of *Cenchrus ciliaris* and seven genotypes of *Cenchrus setigerus*, the IGFRI 3108 and 678 of *C. ciliaris* and IGFRI-76 and 77 of *C setigerus* were selected for higher productivity under semi arid region of India (Bhatt and Misra 1990). Genotypes differed significantly for their CER, related leaf characters as well as in total dry matter accumulation at harvest (Guhey *et. al.*, 2003).

The dry matter yield and leaf area production ranged 44.20 to 79.00 g plant$^{-1}$ and 1656 to 2622 cm$^2$ plant$^{-1}$ respectively in thirty five oat genotypes of different maturity duration. Dry matter yield seems to be dependent more on genotypic characters rather than on maturity duration (Bhatt, 1994).

Among the many lamina chrematistics, specific leaf weight (SLW), defined as the lamina dry weight per unit area, has been reported to have a strong, positive association with with lamina photosynthesis in many crops such as soybean (Bhatia *et. al.,* 1996), rice (Reddy *et. al.*, 1995; Murty *et. al.*, 1993) mungbean (Islam *et. al.*, 1994) and cotton (Pettigrew *et. al.*, 1993). A negative correlation between SLW and photosynthetic rate has also been reported in crops like soybean (Ma *et. al.*, 1995) and tobacco (Liu *et. al.*, 1991). There are also a few reports on the effect of nitrogen on SLW and photosynthesis in wheat (Wojcieska, 1994) and on lamina area and dry weight in wheat (Evans, 1993; Lawlor *et. al.*, 1989) and maize (Girardin *et. al.*, 1985).

## Photosynthesis

Biomass production largely depends upon the photosynthesis process supported with the availability of adequate amount of nutrients and water. In fodder crops, in general, the photosynthetic activity remains constant through out the growing seasons reaching peak at flower initiation on then increased at the end of flowering (Cale and Rea, 1989). Photosynthesis that occurs during vegetative

period, as a whole, was relatively high as compared to other stages, contributing towards dry matter production at level exceeding over cereal and grain crops. However, the photosynthetic rate registers a sharp decline as pod began to develop. The drop is associated with a fall in total nitrogen content of leaves and loss of RUDP activity.

Photosynthesis can be assigned as a possible annual renewable resource for material and energy. Photosynthesis process exhibits enough plasticity so that they could get adjusted easily to changing environmental conditions in any habitat during seasonal growth. (Mooney *et. al.*, 1964, Mooney and West, 1964). The potential to grow over a gradient of habitats may also be affected by photosynthetic plasticity. About 85-90% of the dry matter production of plant is carbonaceous matter derived from photosynthesis i.e. the light dependent reduction of $CO_2$ Carbon balance mode has been used to describe plant growth in relation to light and $CO_2$ level (Monteith, 1965, De Wit, 1960).

Photosynthetic process is followed by series of complex reactions. The production of photosynthesis are consumed through respiration. Rates of these processes are influenced by light, temperature, moisture, food supplies etc. and these conditions are largely determined by the season (Gopal, 1972).

A liner relationship exists between net photosynthesis and total conductivity for $CO_2$ between out side air and the intercellular spaces (Louwerse and Zweeride, 1977). The values of light saturating intensity increased with increasing $CO_2$ concentration (Wilson and Cooper, 1969). At high $CO_2$ concentration, plants grown in strong light have higher rates of photosynthesis than those grow in a week light (Wilson and Cooper, 1969).

The photosynthetic system of a plant is quite well adapted to the temperature-regime of their habitat (Pisek *e.t al.*, 1969). The desert plant also showed a high photosynthetic capacity even at high leaf temperature (Schulze *et. al.*, 1972 b, Bjorkman *et. al.*, 1972). Photosynthetic adoption and acclimation to

low and high temperature may be regarded as two apparently separate phenomena. The superior performance at low temperature of cold adapted plants is attributable to an increased photosynthetic capacity. Photosynthesis is one of the most heat sensitive aspects of growth. Excessively high temperature causes and irreversible inactivation of photosynthesis.

Mooney *et. al.*, (1964) compared the photosynthesis of various plants at 300 and 200 ul $l^{-1}$ $CO_2$. He observed that photosynthesis at 200 ul $l^{-1}$ was on an average 40% less than in 300 ul $l^{-1}CO_2$. At normal $CO_2$ concentration (0.03%) photosynthesis is almost independent of leaf temperature, while at higher concentration the rate is strongly influenced by temperature so that light saturation was not reached at the highest temperature (Gaastra, 1959).

When the leaves have low water potentials the rate of photosynthesis declines. The loss of photosynthetic ability is generally attributed to the closure of stomata of the leaves (Hasio, 1973). The closure of stomata hinders the diffusion of $CO_2$ into the chloroplast and brings about a loss in the photosynthetic ability (Brix, 1962).

There are many reports suggesting that photosynthetic rates depressed due to the reduced chlorophyll concentration (Heath, 1969, Sestak *et. al.*, 1971). But in many natural communities the normal chlorophyll content of leaves is adequate to absorb the available photosynthetic flux (Anderson, 1967) and chlorophyll contents are likely to adjust to the flux available (Rabinowitch, 1951). Photosynthetic rate per unit leaf area changes with leaf age and with ontogeny (Sestak, 1981).

Several of the mineral nutrients have a more or less direct role in photosynthesis. Magnesium as a component of chlorophyll probably exerts its main effect on photosynthesis through chlorophyll synthesis. Neales (1956) estimated that 12.9 and 17.7% of the Mg in white clover and perennial ryegraass, respectively, was associated with the chlorophyll. Peaslee and Moss (1966) found

that chlorophyll content and photosynthesis in corn was linearly related when chlorophyll was altered by Mg additions to the culture. When Mg was supplied to detached leaves, photosynthesis was not improved. Botrill (1970) observed reductions of chlorophyll content and photosynthesis in Mg deficient spinach. Botrill *et. al.*, (1970) also found reductions in photosynthesis due to deficiencies of S, Mn Cu, Zn, Mo and B. Calcium deficiency did not reduce photosynthesis. Reductions of photosynthesis were accompanied by low chlorophyll contents in the case of S, Mn, Zn and Mo deficiencies. Subterranean clover plants grown at low sulfur levels and having a photosynthesis rate 50% of those at high sulfur levels, recovered into a photosynthetic rate comparable to the in high sulfur plants within six days after being transferred to high sulfur solutions (Bouma, 1970a). Deficiency of Mn reduced photosynthesis in oats by 60 to 75% as reported by Gerretsen (1949). Passingham (1964) showed that hill reaction activity in tomato chloroplasts was proportional to their Mn content. He also observed drastic alterations in chloroplast structure in Mn deficient plants. An increase in chlorophyll content of timothy and Yorkshire forage was reported by O' Sullivan (1969).

Crop yield is mainly dependent on the interplay of various bio-physical and biochemical functions of the plants in addition to the impact of growing environment. The stomates are important for the diffusuon of gasses and water vapour which in turn determine the metabolism of crop plants. The arrangement and frequency of the stomatavary widely among the species and within species. Hsiao (1973) reported that photosynthesis is largely dependent on stomatal regulation. Plant productivity is to a large extent determined by the efficiency of photosynthesis under a given environmental condition and available resources. Cowpea cultivars were found to have a high mean stomatal frequency on lower surface of leaf than on the upper surface of leaf and no significant differences in stomatal size, guard cell size and pore size were recorded (Anonymous, 1996). Shivkumar (1996) studied the response of four cowpea cultivars to semi arid environment and found that they did not differ significantly in stomatal conductance or in net photosynthetic rates and the photosynthetic rates increased

with an increase in photon flux density. Farquhar and Sharkey (1982) reported that leaf photosynthesis could be limited by decreased stomatal conductance. In senescing leaves, non stomatal factors were found preponderant in limiting photosynthesis (Field, 1987) possibly mainly through decreased Rubisco activity.

Leaf surface area per plant is an important determinant in production of photosynthesis as suggested by Watson (1947). It is well known that photosynthetic efficiency depends on leaf area, chlorophyll content and the gas exchange. Chlorophyll content in leaf tissue varies with species, age of plants and growing season (Yurkovskii *et. al.*, 1977).

The rate of photosynthetic $CO_2$ uptake is an important component of growth (Leding and Botkin, 1974). Because of the potential utility of growth components in breeding, it is desirable to quantify genotypic and environmental variation in photosynthesis.

Carbon balance model has been used to describe plant growth in relation to light and $CO_2$ levels (Monteith, 1965) and experiments under controlled environmental conditions have established a relationship between light and $CO_2$ exchange (Mc Cree and Troughton, 1966 a & b).

The increased photosynthetic potential in leaves which is reported to be quantitatively inherited (Ojima *et. al.,* 1969), is a possible approach in improving the seed yields. The differences in photosynthetic rates among soybean varieties have been reported by several workers (Curtis *et. al.*, 1969; Dreger *et. al.,* 1969; Dornhoff and Shibles, 1970). Specific leaf weight (SLW), defined as the leaf dry weight per unit area, has been reported to have a strong positive association with leaf photosynthesis in several crops (Bowes *et. al.,* 1972; Delaney and Dobrenz, 1974; Dornhoff and Shibles 1976; Lugg and Sinclair, 1976). The SLW, in turn, has been indicated to be associated with gross leaf morphoanatomical characters (Lugg and Sinclair, 1980; Dornhoff and Shibles 1976).

A significant genotypic variation in rates of photosynthesis and its associated parameters was recorded as vegetative as well as reproductive stages (Kumar *et. al.*, 2002). Photosynthesis is a prerequisite for biomass production and its subsequent partitioning economically important parts to obtain higher yield. A high rate of photosynthesis is always associated with higher productivity, unless sink capacity is limiting (Yoshida 1972). A wide variation in leaf photosynthesis rate has been reported among the genotypes of Pea (Armstrong and Pate 1994), soybean (Kokubun *et. al.*, 1988), rice (Basuchaudhuri and Dasgupta, 1987), Wheat (Kumar *et. al.*, 1998), cotton (Timmannavar and Paatil 2000) and barnyard millet (Kumar *et. al.*, 2000). The stomatal conductance which affects rate of gaseous exchange, exhibited a significant positive association with the rate of photosynthesis. It also had significant positive association with LTD. The positive association of LTD with rate of photosynthesis suggests the role of LTD in maintaining the high rate of photosynthesis by keeping the congenial temperature. Present findings are in the agreement of earlier reports in rice (Murthy *et. al.*, 1991). Wheat (Kumar *et. al.*, 1998) and barnyard millet (Kumar *et. al.*, 2000).

Rate of photosynthesis was highest in TSH followed by *C. setigerus* indicating the intrinsic potential of these species for higher $CO_2$ assimilation. *S. hamata* showed higher productivity over *M. atropurpureum* and thus can be rated as the most potential range legume for semiarid tropics (Bhatt and Tiwari, 2004).

Photosynthetic rate is related to stomatal conductance, photosynthetic enzymes, chlorophyll content and many other factors. Stomatal conductance is responsive to both photosynthetic rate changes and micro environmental conditions. The PN:TR ratio showed positive and significant correlation with photosynthesis, stomatal conductance and dry matter yield. Similarly stomatal conductance has strong positive association with photosynthesis. Therefore, these physiological traits can be considered as primary indices for screening and selection of genotypes for higher photosynthetic efficiency. (Misra and Bhatt, 1995).

Crop yields depend upon both the rate and duration of photosynthesis. Even though it may not be sufficient on its own to raise yields, still increased photosynthetic potential is considered by breeders to be a possible approach in improving yield as it is quantitatively inherited (Ojima *et. al.,* 1969).

Leaf photosynthesis rate has been an important characteristics which is amenable to manipulation provided genetic variation exits (Mythili and Nair, 1996). Such variability exists in several crops such as wheat (Evans and Dunstone, 1970, Austin *et. al.*, 1982, Ghildiyal and Sirohi, 1986, Morgan and Le Cain, 1991), maize (Heichel and Musgrave, 1969), soybean (Buttary *et. al.*, 1981, Curtis *et. al.*, 1982, Bhatia *et. al.*, 1996), chick pea (Gupta *et. al.*, 1989, Mythili and Nair, 1996) and barnyard millet (Subrahmanyam and Rathore, 1999).

Positive association between TDM and rate of photosynthesis have been reported for different crops by several workers (Mythili and Nair, 1996, Kumar *et. al.,* 1998, Subrahmanyam and Rathore, 1999). Positive association between rate of photosynthesis and yield has been demonstrated in different crops (Reynolds *et. al.,* 1994, Kumar *et. al.*, 1998).

High genetic variability has been reported in many crops for photosynthesis rate and related parameters (Ghildiyal and Sinha, 1973, Bhatia *et. al.*, 1995, Mythili and Nair, 1996) and the variability in photosynthesis rate is often associated with the stomatal resistance (Dornhoff and Shibles, 1970, Hobbs and Mahon, 1982). Variability in photosynthetic characters have been reported for different crop plants (Bhatia *et. al.*, 1996, Kumar *et. al.*, 1998, Subrahmanyam and Rathore, 1999). Variation in photosynthesis is often associated with stomatal resistance (Dornhoff and Shibles, 1970, Hobbs and Mahon, 1982), cholorophyll content (Buttery and Buzzell, 1977), leaf size (Bhagsari and Brown, 1986) and and specific leaf mass (Dornhoff and Shibles, 1970; Hesketh *et. al.*, 1981).

However, internal leaf factors like mesophyll and carboxylation resistance are also related to genotypic variation in net photosynthesis (Dornhoff and Shibles,

1970, SharmaNatu and Ghildiyal, 1993). Ontogenetic, diurnal and leaf position dependent variations in photosynthesis rate have been reported (Ghildiyal and Sirohi, 1986, Ghildiyal *et. al.*, 1987, Ghildiyal, 1991, SharmaNatu and Ghildiyal, 1993).

## Transpiration

Transpiration stream may exert indirect influence on the rate of absorption of mineral elements (Hylmo, 1953, Bowling and Weatherley, 1965). Higher $K^+$ concentration increased $K^+$ absorption and $K^+$ - ATPase activity of plant roots (Leonard and Hodges, 1973, Leonard, 1975). Higher rate of transpiration increased the rate of absorption of K+ and plants with higher salt status revealed a gross net higher increase due to the deficiency of potassium reduction in transpiration has been reported by (Dwivedi, 1989) in *Arachis hypogea*. Potassium chloride added to potassium deficient wheat plants brings down transpiration have been recorded at different levels of potassium, and Biebl (1958) has attributed it to the age of the plants i.e., younger ones exhibiting a decrease and older ones an increase. These ions can exercise their influence the osmotic potential (Brag, 1972). Venkateswar Rao and Madhava Rao (1983), while working on pigeon pea noticed reduction in stomatal aperture and transpiration due to potassium deficiency.

Transpiration plays important role in maintaining plant water relations because it produces the energy gradient which causes the movement of water into and through plants. Environmental factors such as, temperature, light intensity, wind velocity, relative humidity, soil moisture and resistance to water movement, leaf area and leaf structure have been found to exert pronounced effect on the process of transpiration (Jung and Larson, 1972, Halle and Bjorkman, 1975) and in turn in whole physiology of plants. The adaptation and ability to survival of plants within a given environment depends upon the extent of heir interaction with the surroundings through the phenomenon such as transpiration, light absorption and energy exchange. The water vapour exchange rate affects the energy budget and temperature of leaf and consequently this not only has a bearing on the physiology

of the whole plant (Gates, 1975) but also influence the surroundings (Ludlow, 1987).

Leaf temperature directly determines the out going radiation flux and in turn water vapour exchange rate (Halle and Bjorkman, 1975, Gates 1980). For leaves with an adequate water supply, transpiration depends upon the sum of the diffusion resistances in the external air and the stomata (Gaastra, 1959).

PAR adversely affects the relative humidity, stomatal and diffusion rasistances and therefore, transfer of water vapour is increased (Nobel, 1977). The rate of transpiration and water content of leaves have an inverse relationship with each other and mainly governed by the relative humidity and temperature. The extent of temperature variation in leaves is species dependent (Yarwood, 1961, Lange, 1975). Transpiration increased with increase in air temperature and PAR in summer and decreased in winter as reported by Haseba *et. al.*, (1967) in *Cetrus,* Bhatt (1990) in *Prunus, Celtis* and *Grewia* and Vandana and Bhatt (1996) in *Sesbania.* Loss of water vapour exerts pronounced effect on the plant growth and productivity (Grace *et. al.*, 1981). The extent of the rate of water loss in subtropical timberline broad leaved evergreen and deciduous trees revealed that the rate of transpiration were higher in deciduous as compared to evergreen trees (Dhyani *et. al.*, 1988, Purohit, 1994). Transpiration is directly proportional to the leaf area and the water vapour gradient between the air the leaf surfaces. It is inversely proportional to the canopy resistance, encompassing stomatal, cuticular and boundary layer resistance.

Increasing temperature may result in further opening of stomata (Schulz *et. al.*, 1972). This cause increase in the rate of transpiration. On the other side low temperature causes freezing of the guard cells resulting in the stomatal closure and in turn the stoppage of the process of transpiration (Drew and Fritts, 1972). Indirectly low root temperatures may affect stomata by inhibiting water uptake resulting in water deficit within the leaves and depression in transpiration (Bababola *et. al.*, 1968, Havranek, 1972).

Some selected species of semiarid regions were evaluated on the basis of physical and physiological parameters like transpiration rate, resistance for water vapour transfer, exchange less water vapour as compared and energy exchange (Bhatt and Misra, 1989). The trees with high diffusion and stomatal resistance for water vapour transfer exchange less water vapour as compared to those trees having low resistance. The leaf energy balance sheet of these trees indicated that most of the energy that was absorbed was lost by re-radiation and this resulted in a negative lower flow of the convectional energy thereby indicating that most of the trees would be able to survive in an environment at a high thermal load.

Researches have shown that potassium is essential for various metabolic activities of living cells. A lack of sufficient supply of K for normal growth causes disturbance in one or more vital process of plant. Evidences show that potassium regulates: (i) synthesis of simple sugar and starch (Ward, 1959), (ii) nitrate reduction (Eckerson, 1924), (iii) nitrogen metabolism (Sinha and Singh, 1984), (iv) phosphorus metabolism (Sinha and Singh, 1982). In addition it has been found that potassium may play an active part in turgor of plant cells (Graham and Ulrich, 1972) as well as formation of organic acids (Yamashita and Fujiwara, 1967, Smith, 1972). Umar *et. al.*, (1993) carried out two experiments in green house with sorghum indicated that K improved the water use efficiency by increasing the stomatal resistance. Higher relative water content in leaves was maintained with K application of early stage with low amount of K (60 ppm). Uptake of K at harvest significantly with the increase in amount of water applied where as at higher K dose (90 and 120 ppm) these differences were negligible. Application of K helped in mitigating the adverse effects of drought via regulating the stomata, retaining more water in the tissues and maintain growth and development. Potassium induced increase in leaf per plant in maize was associated with reduced chlorophyll content. As a result of potassium application considerable increase in leaf area index and stomatal resistance of leaves has been reported in *Arachis hypogea* (Dwivedi, 1989). In *Vigna mungo* water stress caused reduction in water potential, relative water content and transpiration rate to increased stomatal diffusive resistance and leaf air temperature. Potassium treatment led to better internal water

balance (Radhakrishnan *et. al.*, 1966) is vital to many plant functions including formation of sugars and starch, translocation of these within plants, protein synthesis, stomatal action, and as the cation associated with organic anions. Manivel *et. al.*, (1995) reported higher stomatal resistance in plants supplied with added potassium. Wardle and Simpkins (1979), noticed considerable increase in stomatal resistance in KCl treated *Phaseolus vulgaris*. However, Nagarajah, (1979) found potassium deficient leaves to possess higher stomatal diffusive resistance.

Potassium improves water use efficiency through its influence on transpiration and water uptake by regulating stomatal aperture (Bala Subramanian, 1985). Transpiration was about twice as great from high K as from low K leaves. These measurements indicate that stomatal pore space is greater in leaves with high K. Stomatal measurements on alfalfa leaves shown high K having increased stoamtal size and frequency (Cooper Blaser and Brown, 1967). Involvement of K, in stomatal opening has been shown clearly by Humble and Raschke (1971). K concentration in guard cells of open stomata was very high in guard cells of closed stomata very little K could be detected.

## Stomatal Conductance

The leaf conductance can be partitioned into components of the cuticular and the stomatal pathway, i.e., boundary layer, cuticle stomatal anti-chamber, stomatal pore, sub stomatal cavity etc. (Milthrope, 1961, Jarvis, 1971). Gaastra (1959) pointed out that $CO_2$ uptake depends upon both stomatal conductance and a number of biochemical and biophysical variables. The boundary layer conductance of leaves depends on the size of the leaf and wind speed (Grace *et. al.*, 1980). The stomatal conductance has been found to decrease with increasing altitude. Bhatt *et. al.*, (1994) have reported that as the PAR and atmospheric temperature decrease, the stomatal conductance also decreases and they observed the lowest stomatal conductance at 1600 hours. Boundary conductance was found to the maximum around evening hours and minimum around morning hours (Grace *et. al.*, 1980).

The study of stomatal conductance in controlled environment can be done best because in natural environment it is influenced by various factors as interactions between the responses, variability of the natural environment, time response in species with amphistomatous leaves and endogenous rhythms. The conductance of a leaf varies with age, position on the plant and the position in the canopy, as well as upon the season, the time of the day and recent and the current weather. The conductance of the canopy is the sum total of the conductance of all the individual leaves in the canopy.

Stomatal conductance is found to increase linearly with light intensity (Downes 1970) and decrease with increasing temperature (Heath and Orchard, 1957, Lange *et. al.*, 1969). Ambient humidity has been found to affect indirectly on the stomatal conductance through its effect on transpiration and leaf water status (Taylor, 1974). Decreasing PAR and AT adversely affects the relative humidity, stomatal conductance and therefore, water vapour exchange decreased (Bhatt *et. al.*, 1994). Leaf temperature is also found to play important role by determining the out going reradiation flux and indirectly, through its effect on saturation vapour pressure (Gates, 1980).

## Water use efficiency

Production potential of any grassland community or forestland are directly related to water use efficiency of dominant species and are important functional properties of the ecosystem (Rao *et. al.*, 1984). The water requirement of any plant depends upon the stage of growth and it gives them ability to utilize water efficiently and avoid the damaging effects of water stress.

The water potential is an important property in plant water relations. Water loss affects the energy budget of the leaves and decrease leaf temperature and thus may prevent leaf tissues from over heating (Gates, 1976). Woody perennials of arid conditions bear leaves only when the water supply is adequate for transpiration and at the onset of prolonged drought. The leaves of some arid zone

species have a number of characteristics that are adaptive to hot dry environment. Steeply angled leaves reduce mid day solar interception. During the hot periods of the year, the leaves substantially reduce their absorbance of incident radiation by changing their moisture. At these times the light intensity required for saturation of photosynthesis is low and reduction in the radiation absorbed by the leaves therefore, results in a greater water use efficiency (Mooney *et. al.*, 1977). Water loss is reduced dramatically by leaf abscission. The leaf water relations also influences the stomatal behaviors and rate of transpiration and photosynthesis in some plants (Yemm and Willis, 1954, Willis *et. al.*, 1963). It is to be assumed that the reduction in plant water content reduces the net photosynthesis (Slatyer, 1967). Water use efficiency is the amount of carbon fixed per unit of water used. PN/TR ratio which indicates the water use efficiency (means the number of molecules of $CO_2$ fixed per molecule of water transpired) also depends upon the season (Bhatt, 1989).

Singh and Joshi (1979) worked out the relationship between annual rainfall and water use efficiency for some tropical grasslands and forests and reported that the water use efficiency declined simultaneously with increasing rainfall. During vegetative phase plants are found to show higher water use efficiency which gets reduced considerably with maturity (Rao *et. al.*, 1984). It has been found that as the temperature increases the water use efficiency decreases due to decrease in $CO_2$ assimilation rate and stomatal conductance (Prasad and Rajeswar, 1989). Vandana and Bhatt (1996) reported minimum water use efficiency in *S. sesban* and *S. grandiflora* during the summer months.

## Chlorophyll Content

Quantitative estimation of the chlorophyll content is one of the important parameters of structural aspects of the ecosystem and may be considered as an index of primary productivity in the ecosystem (Ovington and Lawrence, 1967, Redmann, 1975). Chlorophyll deserved special attention because it is the light absorbing pigment in the photosynthetic process. Carotenoides function as

accessory pigments in photosynthesis and may also protect chlorophyll from irreversible photooxidation (Naidu and Swamy, 1996). Since it is actual place of photosynthetic activity, it is important to calculate the pigment of standing crop in any plant community. The total chlorophyll in the whole plant community is more uniform than individual plants or plant parts (Gessner, 1949, Bray, 1960). A number of studies have reported on the total chlorophyll and production of plant communities in different climatic regions of the world (Bray, 1960, Bougham, 1960, Golley, 1965, Tieszen and Johnson, 1968, Billore and Mall, 1976, Misra and Misra, 1981).

Total chlorophyll and carotenoid content were more in the shade grown plants. On the other hand the chl a/ chl b is found to be lower in the shade grown plants as compared to the sun plants (Naidu and Swamy, 1993). Shade plants show higher relative content of chl b than chl a (Egle 1960, Goodchild *et. al.*, 1972). The decrease in chl a/ b ratio was usually accompanied by an increase in chl b and specific leaf weight (SLW) which shows the shade adaptive features of plants as reported by Bhatt and Sinha (1990).

Evans, (1993) worked out that photosynthetic capacity and chlorophyll content of leaf, which declined exponentially down through the canopy. As the sprouting starts all the plants exhibit higher chlorophyll a and b content. Naidu and Swamy (1996) while estimating the leaf chlorophyll and carotenoid contents at monthly intervals in deciduous tree species revealed that all the species have minimum carotenoid content during winter and maximum chlorophyll content during summer. Carotenoid and chlorophyll content showed seasonal variations. Higher a/b ratios were reported for most of the temperate communities (Bray 1960). It can also be said as higher the light intensity greater the a/b ratio. Low ratios are the characteristics of the plants from low light intensities. A positive relation has been found between the chlorophyll content and both height and dry matter content (Mall *et. al.*, 1973). In other words the height and dry weight both are the functions of chlorophyll. Total chlorophyll content can be considered as

one of the physiological criteria when selecting the species or varieties for higher productivity (Paliwal and Muthuchelian, 1988).

Bansal *et. al.*, (1999) also observed significant differences between stocks in rice foe leaf area, chlorophyll a, b and total chlorophyll contents. Similarly, Raj and Tripathi (1999) observed correlation of leaf area and chlorophyll with grain yield in rice and suggested these traits as selection criteria.

## Carbohydrates

Starch determination in crops is important since the carbohydrate pool is a determining factor in the growth, development and yield. It is stored as a macromolecular reservoir and enriched in the seeds of cereals and bulbs of plants (eg. Stems of young plants and specially in leaves) as a temporary storage from of energy (Chaplin and Kennedy, 1986).

Lambers and Posthumus (1980) reported that the carbohydrate content of both roots and shoots of *P. lanceolata* was not affected by light intensity. Vandana and Bhatt (1996) reported that the sugar content of leaves and roots in *Sesbania* species decreased as the light intensity decreased. In the stem, sugar content increased with plant age. Starch content in leaves and roots has not been found to show any special trend according to age of the plant while in stem, starch content increased as the light intensity decreased.

As a result of water stress, the sugar content of leaves increased as the starch content decreased (Eaton and Ergle, 1952). A direct correlation between starch content and PN was reported in sunflower and soybean (Potter, 1980). Naidu and Swami (1996) also reported that monthly data on the leaf starch content and PN both expressed per unit leaf area was positively correlated and accumulation of starch content increased with the increasing PN.

## Nitrate Reductase Activity

Nitrate Reductase is one of the most important regulatory enzyme associated with the process of nitrate assimilation and plant growth. Considerable work has been done on cereals and legumes to emphasize the role of nitrate reductase in yield (Johnson *et. al.*, 1976, Migueal, 1981). Its activity is well correlated with protein content and organic nitrogen of nitrate supplied tissues (Srivastava, 1980, Beevers and Hageman, 1969).

The variation in this activity is attributed to the plant species, their developmental stage and environmental factors (Pate, 1980). Most of the work has been done on leaves because of their ability to actively reduce nitrate and their suitability for experimentation. A few studies have been done on stem nitrate reductase activity (Atkins *et. al.*, 1979, Andrews *et. al.*, 1984).

Pizelle and Thiery (1986) reported that the nitrate reductase activity has been found to decrease in order of leaves > branch > inner branch tissue > trunk xylem. Nitrate reductase activity has been found to increase with leaf age but start decreasing when the leaves are fully matured (Muthuchelian *et. al.*, 1986). As the leaf number increase the nitrate reductase activity has been found to decrease (Abrol *et. al.*, 1976).

Jones and Whittington (1982) found that the nitrate reductase activity is affected by season and in seedling stage this activity is highest and upper leaves have high nitrate reductase activity than lower ones. At full bloom stage NRA is found to be highest (Harper *et. al.*, 1972). Plants with a fruit load showed more pronounced diurnal variation in NRA than plants without fruit. Low light intensities and extended dark periods causes diurnal change in nitrate reductase activity (Claussen, 1986). Roots and leaves with higher carbohydrate content showed high NR activity and higher rate of nitrate reduction than carbohydrate deficient organs (Carpts Brandner *et. al.*, 1983, Aslam and Huffaker, 1984) in water stressed conditions.

Nitrate reductase activity has been found to show positive correlation with the yield characters. Fibres and wood weight per plant and yield potential could possibly be related with nitrate reductase activity at seedling stage. All the selection were at par with respect to their nitrate reductase activity (NRA) exhibiting significant differences in seasons.

## Crude Protein

The seasonal and locational variation in crude protein is fairly wide but percent crude protein content is highest when dry matter was at its lowest (Majumdar, 1967). With the advent of monsoon the crude protein values began to drop while in early spring it again rises and at their succulence stage possess practically the same amount of crude protein as the concentrates (Gupta, 1983).

Majumdar *et. al.*, (1967) studied the leaves of 17 species of trees and concluded the during early stages of growth the leaves are rich in crude protein and calcium comparing favorably with the legumes. With the maturity the crude protein and phosphorus content decreased.

Leafiness has been found to be positively correlated with protein content (Paroda, 1975). With the advent of rainy season there is rise in crude protein content (Gupta *et. al.*, 1992). With the increase of tree stuble height the crude protein content also increased (Mendoza *et. al.*, 1983). The crude protein digestibility from green tree leaves was fairly high compared to the older ones (Jain and Beniwal, 1983).

Singh *et. al.*, (2003) indicated that 25 genotypes (IL 97-607, -570, -525, -577, -595, -617, -557, -580, -589, -566, -533, -603, -521, -594, -599, -613, -509, -471, -425, -501, -444, -503, -507, -413 and -487) of exotic *Stylosanthes* germplasm showed that IL 97-589, -594, -595 and -471 were rich in protein, low in fibre fractions and had higher nutrient digestibility. Phenolics and condensed tannins were low in concentration and had no effect on DM and CP digestibility.

Muir and Abrao (1999) indicated that phosphorus application had a positive effect on plot vigour and cover but had no effect on dry matter productivity. Dry matter yield was 112% higher and crude protein concentration was 10% higher for the 6 monthly harvested material averaged over years, entries and phosphorus application. Dry matter production averaged only 298 kg/ha in the first year of harvest and declined progressively each year, while grass competition was very strong. The highest producing entries were *Stylosanthes guianensis* var Pauciflora, *S. scabra* cv seca and Fitzroy as well as *S. hamata* cv Verano.

Cruz-Vazquez *et. al.*, (2000) reported that the protein value was 14.0% for *S. humilis* and 15.8% for *S. hamata.* It is concluded that both legumes are suitable to cultivate on a large scale; however, *S. hamata* has the best agronomic behavior and represents a better forage alternative.

## Flowering

Ison and Humphreys (1984) reviewed the juvenile stages of *Stylosanthes* species and morphological changes at flowering. They covered aspect related to photoperiod responses of several *Stylosanthes* species induction of flowering at subtropical temperatures or photoperiod effects of temperatures interactions with photoperiod responses and effect of moisture stress on flowering in term of flower development, timing and duration of flowering in seed yield components. In a related study Argel and Humphreys (1983) determined the effect of variation in temperatures, soil moisture supply and illuminance on seed dormancy and seed formation of *S.hamata* cv. Verano. They grew plants in the open in successive in both controlled temperature cabinets and in the greenhouse, where shading and watering treatments were varied after the onset of flowering.

The result of both studies indicated that hard seeded ness was strongly developed and was positively related to temperature during seed formation. After seed maturation, seed moisture contain was the main factor governing hard seeded ness, and this quality was negatively associated with temperature during seed

formation. Seed formed under high temperatures had higher contents of lignin (which was concentrated in the counter-palisade cells) and hemicellulose, lower contents of cellulose and shorter palisade cells cutin content was independent of temperature. Dormancy was more strongly developed in the hooked upper articulation than in the hookless lower articulation. Short duration of the soil moisture stress that reduced leaf water potential of minimum values of about -2.5 to -2.8 MPa, and shading treatments that reduced radiation to about 20% of full daylight, reduced seed production, but hard seeded ness was not consistently related with these treatments.

Flowering date, rate of floret appearance, total floret differentiation, duration of flowering, floret abortion lower articulation formation and time to pod maturity were found to be sensitive to temperature. Levels of seed production and hard seeded ness in cv. Verano increased under warm conditions during flowering, thus favoring, possibly even restricting, and the cultivars adaptation to dry tropical environments.

## Seed Yield

The productivity and availability of seeds are important factors in the utilization of forage crops. Forage crops have been bred substantially for vegetative purposes and are often-shy seeders with low seed production. In additions, the forage crops are not allowed to mature and set seed when farmers utilize them as an herbage crop. Thus, the opportunity for seed production becomes limited. The single most important factor holding back the popularization of the recently developed improved cultivars is the non-availability of seeds. There is a need to develop a strategy for organizing seed production at a national level.

Due to its strategic location (15 °27 'N, 75° 5' E) and proximity to the major *Stylosanthes* seed production areas, IGFRI research station at Dharwad has been a major centre for seed production research and research on pests and diseases of *Stylosanthes* in recent years. In the beginning, 4 species, *S. hamata cv. Verano, S.*

*humilis, s. guianensis cv. Schofield* and *S. viscosa* were evaluated for seed production. *S. humilis* was found highly susceptible to anthracnose. Gradually, *S. hamata* and *S. scabra* became popular and the rest were discontinued. At present, almost all farmers and the State Government seed farms grow *S. hamata* and *S. scabra* for seed production.

In India commercial seed of *S. scabra* and *S. hamata* have been produced since the late 1970s, when an estimated 4 ha area was used for seed production in Anantpur in Andhra Pradesh. An estimated area of 450-500 ha was under *Stylo* seed production the 2000-01 seasons. Commercial seed crops are either left ungrazed, or the crops is grazed from June to August before being closed, when the seeds are allowed to from and mature the second method is particularly suitable for Verano. Weed management is very important in *Stylo* seed crops. Some growers manage their seed crop as annuals, planting from seed each year. Despite the simple technology, seed yields in farmers fields for Verano vary from 0.8-1.2 t/ha in dry land conditions to 1.2-1.4 t/ha in irrigated conditions, and compare favorable to the 1.5 t/ha achieved at government experimental stations that use the latest technology (C.R Ramesh, unpublished information).

In India the government plays a limited role in forage seed production, while private companies trade only annual forage crops. The seed productions activity of the perennial range grasses and legumes is vested more with individual farmers who do not belong to any organized sector. Aided by national and international pilot seed production programs, a viable *Stylo* seed industry led by farmers has emerged in the drier regions in India.

In the mid 1980s small farmers in the Rayalseema region, Ananthapur district in Andhra Pradesh, started *Stylo* seed production to meet rising demand from government agencies for their wasteland development programs. Some farmers from the Palasamudram village in Ananthapur were trained in *Stylo* seed production at the Raddipalli state farm of the Department of Animal Husbandry and Veterinary Services. Over the years the improved seed production technology

spread to surrounding villages through farmer – to –farmer exchange of seeds and technical knowledge *Stylo* seed production today is largely concentrated in three mandals of Hindupur and Penukonda Division of Ananthapur district comprising a network of 40-50 villages. The area has increased from only 4 ha in the late 1970s to an estimated 400-450 ha in 2000–01. Earlier estimates of up to 1000 ha in 1995-96 (Ramesh *et. al.*, 1997) were due to an erroneous assumption of irrigated land under *Stylo* cultivation. Most of this increase has come from a replacement of cash crops such as groundnut.

Besides the smallholder farmer-led seed production, government agencies (including state farms at Raddipalli and Mamidipalli (both in Andhra Prdesh), Hessarghatta in Karnataka and Almadhi near Chennai the regional research station of the IGFRI at Dharwad (Karnataka); and the Kearla Livestock Development Board (KLDB) in Dhoni (Kerala) have taken up seed production in the past 20 years. Other recent entrants include farmers in a cluster of village around Dharwad in Karnataka, who have been organized though the NGO Bharatiya Agro Industries Foundation and mostly women self–help groups under an urban aforestaion program of the Hyderabad Urban Development Agency in Andhra Pradesh.

Goswami *et. al.*, (2003) reported that the high yielding genotypes possessed significantly higher values for LAI, CGR, LAD, BMD, SLW and these growth parameters recorded significant positive association with seed yield. Among the biophysical and biochemical parameters, stomatal number and index, stomatal conductance, photosynthetic rate, transpiration rate total chlorophyll content in leaf and leaf nitrate reductase activity were found significantly positive correlation with these traits. The high yielding genotypes also recorded significantly higher values for harvest index, number of seeds per plant, pod yield, number of pods per plant, number of seeds per pod, number of fruiting cluster per plant and these yield components showed significant positive correlation with seed yield.

## Seed Treatment and Seed Germination

### Dormancy breaking methods

Many artificial chemical as well as physical methods have been developed to rupture, remove or dissolve the water impermeable seed coat of legumes or hard and stiff lemma and palea of grasses for getting synchronized germination and also for assessing the true germination percentage in seeds of commercial importance. Scarified seeds can not be stored for a longer period as these lose viability rapidly than the non scarifies seeds (Omokayne *et. al.*, 1995, Reshma *et. al.*, 2002).

### Chemicals

Concentrated sulphuric acid is the most widely used chemical for making the seed coat permeable to water. Its concentration as well as immersion time varies from species to species and depends on seed origin, age, moisture content and storage condition. Acid resistant seeds of *Lupinus* become permeable to water after four to seven hour of soaking. Caustic soda (20-30%) have also been used to scarify water impermeable seeds of many leguminous specie4s besides $HNO_3$ (Biradar *et. al.*, 1988; Girase *et. al*, 2002). Solvents like acetone, petroleum ether, ethyl alcohol etc. have also been used for making the seed coat permeable to water. Ethyl alcohol was found more effective in breaking the coat – imposed dormancy in species belonging to *Caesalpinioideae*, compared to *Mimosoideae* and *Papilionoideae*. Significant increase inper cent germination has also been observed by treating the seeds with $KNO_3$, thio-urea, $GA_3$, ascorbic acid etc. after scarifying the seeds with $H_2SO_4$ (Girase *et. al.*, 2002). In case of grasses gibberellic acid and potassium nitrate have been found most effective and heir role in overcoming dormancy has been discussed elsewhere (Simpson, 1990, Parihar *et. al.*, 1999b).

Nan *et. al.*, (1998) reported that the most effective treatment for reducing fungal infection without reducing seed viability in *Stylosanthes hamata, scabra* were immersion in sulfuric acid for 6 minute, immersion in water at $55^0$ C for 10

minute and immersion in water at 55$^0$C for 5 minute + immersion in sulfuric acid for 3 minute.

**Mechanical scarification**

Mechanical scarification utilizes abrasive elements, particularly the rough surfaces in most of the treatment for breaking the coat-imposed dormancy in hard seeded legumes. However, their practical utility depends upon the type of seed used. Although mechanical methods are not practically possible on commercial scale. But seeds of *Stylosanthes scabra* were scarified satisfactorily by hammer milling in large quantities by Hopkinson and Paton (1993). Dehulling and scarifying machines are in use in parts of Australia for some pasture legumes.

**Hot water treatment**

Hot water has been used successfully for breaking coat imposed dormancy as there are many references in the literature, although there exist considerable variation with the species in relation to optimum water temperature and immersion time required for obtaining normal seedling. Increased germination in pasture legumes viz. *Stylosanthes spp., Clitoria ternatea, Siratro, Desmodium spp.* etc. has been reported and immersion time ranges from one second to 20 minutes. In cast of *Leucaena leucocephala*, immersion time of three to four minutes is recommended, although Oakes (1984) observed that immersion time of two to five minutes at 80$^0$C or two to five second at 100$^0$C was the most effective treatment.

**Heat treatment**

Temperature fluctuation or high constant temperature or mist and dry heat has also been found effective in making the seed coat permeable to water. High constant temperature obtained by heating seeds in heated rotating drums was found effective in pasture legumes (Matin *et. al.*, 1975, Mott, 1979, Paton, 1993).

However, optimum temperature treatments and exposure time vary between species.

**Radiation**

Radiation as means of scarification has also been explored as infra-red radiation (IR), radio frequencies (RF) of 39 MHz and other frequencies like ultra high frequency (microwave 2450 MHz) has been compared and found effective (Rolston, 1978). A legume seed coat is not only barrier to germination but also rich source of secondary defensive substances such as the allelochmicals, and contain higher concentration of an array of toxic non- protein amino acids, pheolic compounds and alkaloides (Parihar *et. al.*, 1996, Parihar, 2000).

**Germination**

Nan, *et. al.*, (1998) reported that the most effective treatment for reducing fungal infection without reducing seed viability in *Stylosanthes hamata, scabra* were immersion in sulfuric acid for 6 minute, immersion in water at $55^0$ C for 10 minute and immersion in water at $55^0$ C for 5 minute + immersion in sulfuric acid for 3 minute. Increasing the salinity levels (0-25 ds/m) decreased seed germination, radical length and seedling height in *S. guianensis*. (Ramirez *et. al.*, 2000).

HU and Jones (1998) recommended to treat seed with water at $80^0$ C for 2 minute up to 8 months after harvest, although freezing for 48 hours before sowing is also efficient in *S. guianensis* CIAT-189.

Mechanical scarification was most effective in breaking dormancy seeds off forage legume *P. venezuelensis* passing through a blender increasing germination percentage after 28 days from 2% in untreated seeds to 53.5%. (Diaz *et. al.*, 1995). Removal of caryopsing glumes of three strain of *C. setigerm* has an enhancing effect on percentage germination but strong of dehusked seeds (caryopsis) rendered them non viable (Parihar *et. al.*, 1984).

GU Hong Ru *et. al.*, 1995 studies that the highest germination rate of (*Panicum maximum*) naked seeds (42.7%) was given when harvested in late against at daily mean temperature of 25.3-26.9 $^{0}$C. Seeds with their glumes removed by hand and sulphuric acid had germination levels of 66.3 and 54.7%, respectively and seeds treated with gibberellic acid at 100 and 150 ppm had germination levels of 59.7-76.7%.

Roy and. Pathak *et. al.*, (1986) studied on *Vigna umbellata* seeds exhibited polymorphoism with variation in size and colour, and found that the brown seeds responded to the $KNO_3$ solution showing higher germination, and the role of seed polymorphoism in germination and seedlings establishment has been discussed.

Gupta and Nayital (1996) conducted an experiment to determine the response of 14 varieties to Lucerne to different pre showing treatments and found maximum germination was in cv. Lucern to treated with hydrogen peroxide (96.66%), followed cold water soaking (90%) and 500 ppm gibberllin (83.33%). Greatest stimulation of germination after 5 days was given by $0.2^{-M}$ thiourea. (Delatorre *et. al.*, 1997).

Manual scarification with sand paper broke the dormancy of *T. resupinatum* whereas scarification and soaking in hoot water both significantly increased germination after 10 days in *A. muricata* from 1% to 90-91% (Medeiros *et. al.*, 1996).

Mechanical scarification with stones increased the germination percentage of (*S. guianensis*) 3-17 days after sowing from 8% (Araiyo *et. al.*, 1996). Germination of *P. maximum* seeds was lowest in control (5%) and highest with scarification (70% $H_2SO_4$) + gibberellic acid (100 ppm) (80%) reported by (Singh *et. al.*, 1995).

The effects of pre-treatments of seeds with various growth regulators and chemicals have been well reviewed (Saxena, 1974, 1989). The efficiency of growth regulators in modifying the accumulation of various reserves during seed development has been reported (Crouch and Sussex, 1981, Malik *et. al.*, 1987). Seeds harvested from NAA treated plants exhibited better germination, improved water imbibition and thinner seed coat as compared to controls. Hormonal treatment of mother plants is known to alter seed coat thickness (Gray and Tomas, 1982). According to Nooden *et. al.*, (1985) cytokinin and minerals available to the developing seeds controls seed coat thickness. Seed germination of fodder cowpea, sorghum, berseem and vetch was stimulated by soaking the seeds in 100 ppm cycocel for 1 hr, B-9/phosphon for 4hr and 100 ppm B-9 for 4 hr, respectively (Yadava and Srinath, 1975).

The subterranean clover seed treated with thiourea $10^{-4}$ M induced the germination in dormancy seeds. Germination was also promoted by $10^{-1}$ M thiourea at 30 $^{0}$C (Lip and Ballard, 1970). Seed treatment of maize and cowpea with two natural for increasing the storage life of these seeds. However, emblin (50 ppm) has stimulating effect on germination (Sinha *et. al.*, 1980). Etherel (0-25 µg) applied on freshly harvested seeds of *S. humilis* increased the germination percentage more effectively than BA (0-500µg) but acted synergistically when used in combination. Use of chemicals such as conc. $H_2SO_4$, potassium hydroxide and hot water treatment may also promote the germination percentage. Besides germination, these treatments also encouraged the early plant growth in butterfly pea (Hall, 1992). Hot water treatment for 90 seconds improved germination in *Stylosanthes* (Rai, 1984). Rai and Kanodia (1982 a) reported that seed obtained from phosphate applied plots exhibited better germination in *S. guianensis* as compared to these from unfertilized pods.

Ram *et. al.*, (1976) found that the seedling growth of *Phaseolus radiatus* L. was slightly enhanced by GA and auxins. Ross and Hegarty (1980) studied action of growth regulator on Lucerne germination and growth under water stress. In this, Lucerne seeds were germinated in range of PEG and NaCl solutions kinetin +

ethrel completely remove the block of germination through the release of osmotic stress, thus allowing the germination to proceed as a normal condition. Ethrel + kinetin brings early growth.

Pandey (2003) reported that temperature optima of 22 $^0$ C, darkness and $GA_3$ (25mg 1-1) are factors promoting germination of *Cryptomeria Japouica*, D. DON. Species. Poor germination at high temperature under both light and dark conditions may be an indication of thermo sensitive nature of this species.

Seed coat softening treatments eg. boiling water treatment (98 $^0$C for 30 seconds) to *S. punica* seeds (Graaff and Van Stadun, 1983) and concentrated sulphuric acid treatments for 4 hours to *Sesbania drummondii* are required for maximum, germination (Easstin, 1984).

The smaller seeds of *Sesbania aculenata* had faster seedlings emergence, the relative growth rate and rate of increase in seedling height was higher for larger and heavier seed (Pandey *et. al.*, 2003).

Increased germination of *Lavendula angustifolia* (Aoyama, 1996) and *Sapindus trifaliatus* seeds (Naidu *et. al.*, 2000) have resulted from exogenous application of Gibberellic acid ($GA_3$). Applying $GA_3$ in many crops like lettuce and Wheat (Inoue, 1991, Lenton and Appleford, 1991) has also broken seed dormancy.

The variation in seed coat hardness/ quality of different provenance results in different germination. The variation in hardness of seed (Kaul, 1965) is possibly due to different environmental conditions of their place of origin, degree of maturation, time of collection and length of storage period (Ginwal *et. al.*, 1995).

Pre-showing seed treatments of $GA_3$ (100 ppm) improved the growth and vigour of seedlings after emergence as compared to other treatments in *C. ciliaris* (Bhatt, 2001).

However, in case of range grasses, dormancy is not so acute and a seed germinates after the dormancy period is over. Although, germination in caryopsis is faster and complete than the dispersal units (Parihar *et. al.*, 1984 a,b; Parihar *et. al.*,1988 a,b, 1999a;, Parihar and Tomer,1999, 2001).

Rai and Kanodia (1982 a) reported that seed obtained from phosphate applied plots exhibited better germination in *S. guianensis* as compared to those from unfertilized plots.

## Effect of growth hormone and nutrients on growth, physiology and seed yield

The processes of growth regulation and differentiation in plants are controlled by endogenous chemicals, some of which are indole acetic aicd (IAA), gibberellics (GA), zeatin, abscisic acid (ABA), ascorbic acid (AA) and ethylene. Plant growth regulators are known to modify the growth and development patterns of plant by exerting profound effect on various physiological processes and hence regulating the productivity (Brenner, 1987, Clifford *et. al.*, 1986, Patrick, 1988, Setia *et. al.*, 1991). Growth regulators have very complex role in nodulation and plant growth (Verma and Dubey, 1974, Abbas and Abotabikh, 1976, Torrey, 1976) as well as on nodulation (Artamonav, 1975). The plant growth regulators are expected to play an important role in rectifying by hurdles in manifestation of biological productivity.

Among growth regulators, NAA was fond most effective. Foliar application of NAA increased the growth parameters viz; plant height, number of branches/plant, leaf area index, dry wt/plant and plant attributes. In a filed experiment foliar applied NAA enhanced biological yield, pods per plant, weight of individual pods in pulse crops (Nickell, 1978). Foliar application of NAA (50 and 100 $\mu g^{-1}$) to lentil (Lens culinaris medic) plants reduced plant height but caused increase in number of branches (Setial *et. al.*, 1993). Kelaiya *et. al.*, (1991) worked out that growth hormones or growth retardants enhanced physicological efficiency of the groundnut. There is evident that IAA is involved in the pattern of

grain weight the ear. Positive correlation has been found between the increase in IAA concentration and the rate of dry weight accumulation of grains between and within the spikelet (Bangerts *et. al.,* 1985). Pillai and Chandhoke (1961) observed that the spraying of $GA_3$ at the seedling and adolescent stage of sorghum with concentrations varying form 0.1 to 30 ppm gave significantly higher straw yield under Rajasthan condition. The lower concentration accelerating plant height and leaf production, where as the higher ones retarded the growth of these traits. The straw production under $GA_3$ treatments was correlated with leaf number, but the grain filling was adversely affected. They concluded that $GA_3$ might not have much favorable influence on the growth, maturity and yield of sorghum except on vegetative stage. Foliar spray of GA (50 ppm) and ethaphon (1000 ppm) and its soil application 2.0 mg/pot tended to increase the growth of *Zoysia japanica* cv Mayer (Borden and Campbell, 1985). Maize plant sprayed at 9 leaf stage with 1000 ppm tryptophan IAA, increased the root numbers at lower nodes while reducing upper nodes (Koyabashi and Mizutani, 1971). WL83801 showed high biological activity rapidly suppressing the growth of *Lolium perene* (Foreman, 1985).

Kanwar and Chopra (1961) observed that the yield of berseem could be increased markedly by spraying with $GA_3$. Field studies conducted on the effect of $GA_3$, phosfon, AA, B-nine and CCC on the growth, flowering and seed yield of cowpea (*Vigna unguiculata)* showed that the branch number, leaf number and dry matter percentage increases, but the effects being not proportional to the concentration used (Yadava and Sreenath, 1975a). Abou-zied (1973) and Masoud *et. al.,* (1973) treated four week old *Cannabis sativa* plant with $GA_3$ and IAA (0-250 ppm). $GA_3$ significantly increased the height but weight of leaves was reduced considerably. Where as IAA could not produce any significant change. Similar type of results was also reported by Zabluda *et. al.,* (1973) and Takahashi (1973)) also reported similar type of results on *Populus tremuloidis* and *Oryza sativa* L. respectively.

Patil and Lall (1973) treated wheat (*Triticum aestivaum* L.) cv. Sarbati Sonora seed with $GA_3$ and ascorbic acid before sowing and observed that pretreatment of seeds enhanced the height of main stem. Vegetative growth as stimulated both by ascorbic acid and $GA_3$ but later proved superior. Effects of NAA on cell division and elongation in the presence of endogenous gibberllic acid (Brain and Hemming, 1958) have resulted in increased plant height in blackgram (*Vigna mungo* L.).

Ved Prakash (1966) and Yadava (1970) found that the application of CCC and B-nine increased the nodule number, N content and its fixing ability in Berseem (*Trifolium alexandrium*). It has been observed that low concentration of IAA and $GA_3$ is much effective to nodulation and plant growth as compared to higher doses. Requirement of NAA, 1-4 D and KN are also effective at very low dose for optimum response (Singh and Kumar, 1989). (Gill *et. al.,* 1973) worked out that foliar spray of cycocel (CCC) at 2 kg a.i./ha increased the seed yields of oats significantly. In forage sorghum, an application of mefluidide (0, 0.35, 0.07, 0.14 or 0.28 kg/ha) reduced the plant height and top yields but number of tiller per plant was increased. Roots weight was less for treated plants. By releasing apical dominance and stimulating new tiller production, maintained the plant longer in a more juvenile stage of growth (Matches *et. al.*, 1985). Chailkhyan *et. al.*, (1973) reported that cycocel application either in soil or foliar considerably increased the number and weight of nodules/plant.

Application of kinetin and B-IAA bounded the above ground weight of Lucerne plant with 24 fold increase in the nodules number and size of root hairs (Sabel-Nikova *et. al.*, 1987). Philips and Chilcote (1981) reported that application of TIBA (10 ppm) promoted the elongation of both primary stem and auxiliary branches and also raceme formation on both stem and branches, which resulted in 5-fold increase in total branches length/primary stem and highly significant increase in total raceme production of Lucerne corp. Root growth of Lucerne was found to be greatly improved in the soil treated with small quantities of 3, 5 di-iodo 4-hydroxybenzoic acid and $GA_3$. The root length was recorded in the treatment

orders loosened subsoil + lime stone (11.2 t/ha), loosened subsoil, topsoil treated with DIHB and top soil created in various treatments were 66.3, 61.0, 51.2, 49.0 and 33.2 respectively with corresponding mean dry weight yield of shoot in each treatment 7.05, 6.08, 5.59, 4.65, 3.08 g/plant (Saini, 1979).

Subramanian and Palaniappan (1981) reported that foliar spray of nitrogen and phosphorus is as good as soil application. Foliar application of $KNO_3$ is reported to bring out spectacular changes in yield of pulse crops (Sinha, 1974). In alfa alfa (*Medicago sativa*), application of 17 and 140 g of TIBA (2,3,5 triodobenzic acid) per ha, increased the leaves/ plant and the plant height (Hale, 1971). Application of $KNO_3$ and ethereal improved the physiological traits like biological yield, leaf weight etc. and resulted in an increased yield by 24% and 21% respectively over control. NAA 5 ppm exhibited maximum yield (15.28 q/ha) as reported by Shinde *et. al.*, (1991). Yoshida (1972) attributed that potassium included variation in crop yields to its positive effect on leaf area. Greater K/Na ratio has been recorded in resistant varieties of cotton and rice (Cooper *et. al.*, 1967, Chu *et. al.*, 1976). Potassium induced increase in leaf area per plant in maize was associated with reduced chlorophyll content. As a result of potassium application considerable increase in leaf area index has been reported in *Arachis hypogea* (Dwivedi, 1989). Very high concentration of potassium may adversely influence rice growth (Datta and Guha, 1951). Enhanced level of nitrogen brings down the total sugar in the culm, where as, potassium lessens such effect of nitrogen (Kundu and Sircar, 1969). Plant nutrition particularly phosphorus enhances nodulation and root growth under adequate soil moisture conditions (Freire, 1984).

Chatterji *et. al.*, (1976) studied the effect of foliar application of IAA and $GA_3$ on dwarf variety IRS and tall variety Lalisail. A slight stimulatory effect on photosynthetic $CO_2$ fixation was observed in plants treated with $GA_3$, IAA. $GA_3$ considerably increased the translocation of post flowering photosynthesis over the grain filling periods while IAA treated plants maintained slightly higher rate of photosynthesis over the same period, indicating possibly delayed senescence of

leaves. Further stimulating effect of $GA_3$ was noticed invarious crops (Spiker *et. al.,* 1976, Saniewski, 1977, Bhattacharya *et.al.*, 1978). Cole *et. al.*, (1972) applied 100 mg $GA_3/10m^2$ to Lucerne cv. *Mesa sirsa* as a foliar spray and observed that it reduced the photosynthesis, respiration and affected the carbohydrate translocation and consequently the sink capacity. Photosynthesis of corn was reduced when N was withheld from the nutrient solution (Ryle and Hesketh, 1969). The reduction in photosynthesis was related to increased stomatal and mesophyll resistance to $CO_2$ diffusion. Photosynthesis in subterranean clover decreased rapidly after plants were transferred to N- free solutions (Bouma, 1970b). Leaf area expansion decreased more rapidly than did photosynthesis Apel and Lehman (1969) studied N response of several barley cultivars and found photosynthesis of one cultivar to decrease from 208 to 14.0 mg $CO_2/dm^2/har$ as N in the nutrient solution was reduced from twice to one tenth the normal concentration. Other cultivars responded similarly, but not to the same extent near linear increases in photosynthesis have been demonstrated in rice leaves with increases N content (Murata, 1969, Watanabe and Yoshida, 1970). The striking response of photosynthesis in rice leaves as N content increased to 6% and is in sharp contrast to the contention by Watson (1952) that N fertilization mainly caused an increase in leaf area, with much less effect on net assimilation. If this relationship observed in rice holds for forage grasses, ten the main effect of added N may be to increase the photosynthetic capacity of leaves. High N may stimulate photosynthesis nearly as much as phtosynthate utilization and perhaps to a degree because of increased photosynthate utilization. This conclusion is supported by Thomus and Weier (1962), he observed that starch accumulated much more rapidly in choloroplasts of N-deficient bean plants than in plants at high N levels. Nitrogen in the form of $KNO_3$ did not appear to enhance photosynthetic rte of *Digitaria erintha* (Wolfson and Cresswell, 1985). Comparative photosynthetic performance of $C_4$ (*Zea mays* L.) and $C_3$ grass were evaluated under the influence of form and concentration of N supply (Cresswell and Prophet, 1985). It was reported that increased supply of N resulted in shift in both the temperature optimum as well as optimum level of light intensity for photosynthetic activity.

Nitrogen used in the form of $KNO_3$ (10 mM) reduced 70% nitrogenase activity and 50% leghaemoglobin content of *Medicago sativa* but nitrogen content of plant increased from 0.3 μg N to 12.5 μg N/g FW. Growth of auxiliary shoots and roots were increased with a steady state leaf photosynthesis (54-113 u mole $CO_2$ / mg chlorophyll) and translocation speed (0.37 – 0.56 cm/min). Higher N concentration caused decreased in N fraction rather than in photosynthesis (Cot'Ya, 1989). While lower concentration of nitrogen (1.2 mM) increased nitrogen fraction and photosynthesis during bud formation and early flowering period. Similarly increasing concentration of $KNO_3$ increased the N uptake and NR activity. A significant positive correlation was found between carbon fixation rate and in vitro PVR activity of *Pennisitum purpuria* and *Chloris gayana* (Venkataraman and Das, 1985).

Phosphorus plays a primary role in photosynthesis because of its role in energy transfer. Early steps in the photosynthetic process involve conversion of adenosine – 5-diphosphate (ADP) and inorganic phosphate to adenosine triphosphate (ATP), and the reduction of nicotinamide adenine dinucleotide phosphate (NADP). These P containing compounds serve as energy acceptors and donors, and as such make P an absolute requirement for photosynthesis. There is little information however, to indicate the level of P in tissues of forage species, or other plants, at which photosynthesis is maximum. Watanabe and Yoshida (1970) found a reduction in photosynthesis of rice from 84 to 22 mg $CO_2$ / $dm^2$ / hr as P was reduced from 0.45 to 0.065% of leaf dry weight. Bottrill *et. al.*, (1970) found a similar reduction of photosynthesis in spinach caused by P deficiency.

Increase in the rate of photosynthesis and grain yield with added potassium has been reported in tabacco and cotton also (Patil *et. al.*, 1987 and Suh *et. al.*, 1990). Manivel *et.al.*, (1995) has reported higher rate of photosynthesis in plants supplied with added potassium. There are several indications, however, that K may have indirect effect on photosynthesis. Peaslee and Moss (1966) measured optimum level of porosity of corn leaves and found leaves high in K to be several-fold more porous than K. Potassium also influences the photosynthesis (Cooper *et.*

*al.*, 1967, Marchner and Mix, 1974) and respiration (Okamoto, 1967a), since it is involved in several places as an activator (Evans and Sorger, 1966). Behboudian and Anderson (1990) noticed potassium deficiency to adversely affect photosynthesis.

Effect of K on photosynthesis have been studied more than those if any other element. K deficiency reduced photosynthesis in nearly all studies. Gregory and Richards (1929) investigated the effect of N, P and K deficiency on photosynthesis of barley. They observed that K deficiency reduced $CO_2$ uptake, but the effect of N and P were low. Ozbun *et. al.*, (1965a, b) reported that K deficiency in bean leaves caused reduced $CO_2$ uptake and $O_2$ release in the light. The effect was much greater in immature than in mature leaves. They concluded that K deficiency decreased the capacity of leaves to produced photosynthetic reluctant and of the reluctant produced, more was used to reduce $O_2$. Reduction of $O_2$ is a waste of energy which could otherwise be used to fix $CO_2$. Watanabe and Yoshida (1970) found a reduction in $CO_2$ uptake of rice leaves from 34 to 13 mg/dm$^2$/ha when K content dropped from 1.9 to 0.5% of the dry matter. Cyclic photophosphoryltion (ATP production) was reduced similarly. The effect on photophosphoryltion indicates that K participates directly in the photosynthetic process. One manifestation of K deficiency that may be related to photosynthetic efficiency is reduced specific leaf weight. Gregory and Richards (1929) reported a reduction in specific leaf weight from 375 in high K leaves to 303 mg/dm$^2$ in K deficient barley leaves. Similarly, Cooper *et. al.*, (1967) observed a reduction from 30.5 to 23.9 mg/dm$^2$ in alfalfa leaves due to K deficiency. This reduction in specific leaf weight might to due to lower photosynthesis rates and /or higher respiration and therefore, lower reserve in the leaf or to a direct effect of K on leaf anatomy.

Peaslee and Moss (1966) found than K concentrations for maximum photosynthesis in corn leaves were in the range of 1.1 to 1.5% of the dry matter. They suggested critical leaf nutrient concentrations might be determined by photosynthesis measurements. Results from experiments on photosynthetic

response of alfalfa to increasing leaf K concentrations (Cooper, 1966, Cooper *et. al.*, 1967, Kimbrough, 1969). It appears from these data the K concentrations required from maximum photosynthesis are higher in alfalfa grown in the filed, than for that grown in the greenhouse. Critical concentrations near 1% are apparent from greenhouse grown plants, while photosynthesis of filed grown leaves did not appear to have reached a maximum fat 2.5% the highest concentraion attained. Peaslee and Moss (1966) found reduced photosynthesis in maize leaves deficient in potassium. The conductivity and photosynthetic rates of these leaves enhanced, if they were dipped in $KNO_3$ solution after excision. Peaslee and Moss (1968) also found that initial potassium deficiency result in closed stomata however with increasing severity of potassium deficiency results in photosynthetic capacity of mesophyl cells is also influenced. In cluster bean, foliar application of 4 kg $KNO_3$/ha twice at pre-flowering stage developed the potential strength for longevity of green leaves and increased photosynthesis ascribing 50% more reaping value over control (Sinha, 1978b).

Sinha (1988) highlighted the role of potassium in plants during different types of stresses. He also pointed out that plants with sufficient potassium exhibited greater stomatal resistance during water stress. Behboudian and Anderson (1990) noticed potassium deficiency to adversely affect photosynthesis. Different results have been obtained employing different salts of potassium that indicates the importance of accompanying anion with $K^+$ on potassium uptake (Buwalda and Smith, 1991). Kanwar and chopra (1961) observed that the yield of berseem could be increased markedly by spraying with GA. It has been observed that low concentration of IAA and $GA_3$ are much effective to nodulation and plant growth as compared to higher doses. Requirement of NAA, 2-4 D and Kinitin are also effective at very low dose fore optimum response (Tejbir Singh and V. Kumar, 1989).

Foliar application of gibberellic acid ($GA_3$) in a dioecious cucurbit *Trichosanthes dioica* increased the number of female flowers by 23% and decreased abortion of female flowers by 20% resulting in increased fruit setting by

18.7%. It increased length, girth and weight of the fruits and also content of carbohydrate and ascorbic acid. (Basu *et. al.,* 1999).

Field studies conducted on the effects of GA, Phosfon, AA, B-nine and CCC on seed yield of cowpea (*Vigna unguiculata*) showed that the highest grain yield (4.60 q/ha) was obtained in B-nine (1000 ppm) treatment, followed by 100 ppm Phosfon (4.02 q/ha) as compared to the untreated (control) plants, yielding only 2.19 q/ha. Pods of treated plants matured 2.9 days earlier than those of the control. The thousand grain weight increased under 1000 ppm of B-nine followed by that under 500 ppm Phosphon (50 ppm), AA (50 ppm) and CCC (500 ppm) respectively (Yadava and Sreenath, 1975a). Sinha and Mishra (1991) observed that the foliar application of 50 ppm NAA and 10 ppm maleic hydrazide at 45 and 60 days in Siratro enhanced the water soluble sugar in flowers and photosynthetic pigments in leaves which caused the increase in seed yield over control. Foliar application of 0.2% triachontanol (Vipul) increased seed yield by 15 percent over control in Siratro. Paul *et. al.*, (1973) induced the growth in *Avena* stem through $GA_3$ but seed yield per plant was reduced.

Kalita (1995) reported that foliar applied 3% $P_2O_5$ + 100 ppm NAA showed highest seed yield and harvest index (7.65 q/ha and 28.76% respectively) in green gram. The increased yield performance of treated plants was associated with higher number of pods/plant and seeds per pod. Yadav *et. al*, (1978) reported that foliar spray of $GA_3$ (25 ppm) and phosphon D (50 ppm) at 35 days after sowing and second after third cut increased the seed yield of berseem ranging from 7 to 35 percent. Foliar application of 30 ppm planofix to berseem increased the seed yield significantly over control (Yadav and Verma, 1981). In another finding the foliar application of planofix (0.2%) develops potential flower (24.3% water soluble sugar) of berseem (Sinha, 1984) and further it provides the plant at a physiological functional state for longer period because of that, period left is utilized for synthesizing enough sugar (0.5%). With the result it reflected in building up of enough tiller (74.4)/$m^2$ to synthesize (84/5 tillers) and high number of grains (7.30 g/pant) over control (28.3 tiler/$m^2$, 67.3 boll/ 5 tillers and 3.5 g seed yield/ plants).

Foliar application of 20 ppm planofix, 1500 ml cytochrome and 100 ppm CCC gave highest seed of berseem. In berseem, two spray of planofix (50 ppm), $GA_3$ (45 ppm), Phosfon-D (50 ppm), B-9 (500 ppm) and CCC improved seed yield by 7-35% (Yadava *et. al.*, 1978). The planofix applied twice before anthesis, develops the potential flower by accumulating higher water soluble sugar. This resulted in higher seed yield. The grains weight and yield also increases by application of 500 pm B-9 followed by 50-ppm phosphon-D. Similarly, Jain and Yadav (1981) also found significantly high yield in phosphon-D (100 ppm) treated cowpea plant over control.

Similarly foliar application B-9 and Alar (5-15 kg/ha) at bud formation stage decreased the length of flower tube and significantly increased the seed yield of red clover (Fojtik *et. al.*, 1976) of the different growth regulating substances. In berseem crop, foliar application of 10-20 mg $GA_3$ at 30 days old plants resulted in high seed setting and thus significantly gave high seed yield (Yadava *et. al.*, 1978). Further increase in seed yield was possible if $GA_3$ (200 ppm) applied along with 80 kg $P_2O_5$/ha mainly through meeting the requirement of P during reproductive phase (ABD-EL-Latif, 1986).

Seed yield of Lucerne was increased with foliar application of IAA (50 ppm) and NAA (10 ppm) as reported by Dhaliwal and Bains (1983a) and with SADH and succinic acid. This increased the number of seeds/ pod and number of pods/ raceme. TIBA and GA, on the other hand, could not influence much on the reproductive parameters.

The application of growth retardants, i.e. CCC 3 kg/ha (at early bud formatin), 2 kg + MH-NA (shooting stage) 0.01% oxamine (bud formation, post flowering) 0.008% nitraburte (3 application) and 0.01% succinic acid gave 14%, 19%, 21%, 17%, and 11% higher seed yield over control (Tsybul'Ko and Buryk, 1985). Similarly foliar applcation of B-9 (1-100 ppm) twice (at bud formation + flowering stage) significantly increased the seed yield of Lucerne. Foliar application of 50-ppm planofix increased the seed yield of Lucerne from 2.43 to

3.30 q/ha (Yadava *et. al.,* 1984). Thus it seemed that growth retardant applied before flowering and at flowering might be effective in elevating seed setting in lucerne crops.

Seed production in *Stylosanthes* improved with basal application of 40 kg $P_2O_5$/ha (Kanodia *et. al.*, 1985). Shelton and Humphreys (1971) found in *S. humillis*, that inflorescence density was positively related to addition of phosphorus and the effect increased the seed yield by 20% under conditions where phosphorus addition increased yield of plant type by 54%. Rai and Kanodia (1980a and 1982a) also observed that seed test weight of *S.humilis* and *S. guianensis* was slightly increased by the application of phosphorus. The increase in seed yield over control in Siratro, *S. gracilies, S. humilis* and *Desmanthus virgatus* were 68.18%, 62.25% with 40 kg $P_2O_5$ 45% and almost 300% with 60 kg $P_2O_5$ respectively (Rai, 1981). For enhancing the seed production, in *S. hamata*, the highest seed yield was obtained with 450 kg SSP/ha on sandy loan red soil (Singh, 1981).

Foliar spray of 4 kg $KNO_3$/ha has beneficial effects on seed production of *Sylosanthes hamata* (Dwivedi, 1994-95). Phosphorus deficiency may affect seed production by restricting growth of vegetative canopy prior to transition of flowering and this is reflected in fewer sites of floral initiation and delayed floral development (Shelton and Humpreys, 1971, Robinson and Jones, 1972).

In *Stylosanthes humilis* and *Macroptilium atropurpureum*, high uptake and P and its efficient utilization particularly in reproductive development phase produced high inflorescence density and seed (Velayudhan *et. al.*, 1979, Gibert *et. al.*, 1987). Rai and Kanodia (1980) reported that basal application of phosphorus (60 kg $P_2O_5$/ha) significantly gave high seed of *Stylosanthes humilis* without effecting the seed size. Response of K and P on flower development and seed setting of berseem and Lucerne have been documented by Sinha (1986). Foliar fertilization of P at grain filling stage gave good results in corn, sorghum and soybean (Hanway, 1980).

Fock (1970) reported that application of 1.2 g $CuSO_4$/pot + 1.8 q K/pot applied shortly before flowering significantly increased the seed yield of Lucerne under deficient condition flower bears small number of non-visible pollen and thus resulting in low seed yield (Graham, 1972).

Potassium has been found to play a significant role in water balance and translocation of food material. Since there is crop of N content at late stage of plant growth, hence $KNO_3$ application might be helpful in strengthening the source-sink relationship of 60 kg $P_2O_5$ + foliar spray of 2.5 kg super phosphate + 2 kg $KNO_3$/ha increased the seed yield ascribing either to increase in number of balls/plant or seed weight (Sinha, 1988). This was mainly due to increased synthesis and upward translocation of sugar towards the reproductive integument with elevated activity of photosynthetic apparatus. In another experiment application of KCL (10 g/L) + borax (4 g/L) augmented the use of synthate in development of potential flower at al sites and consequently the grain growth resulting into high seed yield of berseem (Sinha, 1984). Belonogov *et. al.*, (1983) applied 5 mg $GA_3$ or 10 mg 6-benzylaminopirine/1 to red cover at the flowering stage and increased the seed yield by 15-20%.

Tayo (1981) conducted three filed trials on three varieties of cowpea grown as a mono-crop or interplanted with maize was sprayed with a combination of P, K, S or N, P, K, S in solutions containing 100, 100, 100 and 41 mg/l of N, P, K and S respectively on the onset of flowering or two weeks latter. Early seasons spraying of N, P, K, S or P, K, S increased vegetative development and seed yield was increased by 80-225 kg/ha in Prima and 160-218 kg/ha in Vita-5. In all cases of enhanced growth and yields spraying at flowering was most beneficial than spraying two weeks latter whilst N, P, K, S evoked greater response than P, K, S. The results suggest that foliar spray of nutrients during the post flowering period enhanced seed yield in cowpea by ensuring prompt delivery at mineral nutrients to the site of photosynthesis at a time when nutrients depletion in the leaves and reduced efficiency of mineral nutrition uptake by the roots limit the supply of photosynthates to developing reproductive organs. Potassium deficiency causes

accumulation of total and reducing sugars and non-protein nitrogen in Helianthus annuus and a decline in number and weight of seeds and total yield. Increase in protein level was also noticed with low potassium (Bisht *et. al.*, 1985).

Foliar application of $KNO_3$ (4 kg/ha) at 30 and 45 days of crop growth increased the pod formation, pod retention capacity and seed test weight which resulted in gaining 53 percent more reaping value and 17 percent higher harvest index over control in clusterbean. This is caused due to high water soluble sugar and efficient chlorophyll synthesis for a longer period. Sinha (1988a) found a basal application of potassic fertilizers (10 kg $KNO_3$/ha) gave satisfactory results in reaping potential seed yield of berseem crop where 80 kg $P_2O_5$/ha has been used as common dose to experimental plots.

The application of Boron @ 3.0 kg/ha help in Lucerne seed production (AICRPFC, 1985). Boron improved the seed yield in *Trifolium repens* (Johnson and Wears, 1957), *T. pratense* and *Medicago sativa* (Mishra and Patil, 1987). In sorghum foliar application of boron twice before anthesis resulted 14% more seed yield (Misra *et. al.*, 1991). The Boron (150 ppm) application also increased the flower weight, flower number and ball number resulting into higher seed yield in Lucerne by 28 percent (Sinha, 1992). Boron application in the form of borax (150 ppm) twice after 3$^{rd}$ cut improved the synthesis of sugar and enhanced its translocation in reproductive parts. Its application increases the flower weight, flower number per bal resulting into higher seed yield by 28 percent over control.

There is evidence that IAA is involved in the pattern of grain weight within the ear it was observed that concentration of IAA increased 8 days after anthesis in wheat reaching maximum 15-20 days and after that it was dramatically declining. Positive correlation has been found between the increase in IAA concentration and the rate of dry weight accumulation of grains between and within the spikelet (Bangerth *et. al.*, 1985). Graeba (1984) found that the more rapid accumulation of starch in large grained cultivar was paralleled by differences in the IAA content of

grains. In contrast abscisic acid concentration was higher in small sized grain. Infect, IAA promoted the starch accumulation in wheat.

Yadava (1975) obtained higher green matter and seed yield in Berseem (*Trifolium alexandrinum*) plants due to increased chlorophyll content in leaves obtained through the application of GA, CCC, B-nine and Phosfon all applied singly. Kanwar and Chopra (1961) observed that the yield of Berseem (*Trifolium alexandrium*) could be increased markedly by spraying with $GA_3$. In alfalfa (*Medicago sativa*), application of 17 and 140g of TIBA (2,3,5-triodobenzic acid) per ha. resulted in 60% increase in seed yield over that of the control besides increasing the leaves/plant and reducing the plant height (Hale, 1971).

Field studies conducted on the effects of $GA_3$, Phosfon, AA, B-nine and CCC on the growth, flowering and seed yield of cowpea (*Vigna unguiculata*) showed that the branch number, leaf number and dry matter percent increases but the effects being not proportional to the concentration used (Yadava and Sreenath, 1975a). The highest grain yield (4.60q/ha.) was obtained in B-nine (1000 ppm) treatment, followed by that under 100 ppm. Phosfon (4.02q/ha.) compared to the untreated (control) plants, yielding only 2.19 q/ha. Pods of treated plants matured 2-9 days earlier than those of the control. The 1000 grain weight increased under 1000 ppm of B-nine followed by that under 500 ppm, Phosfon (50 ppm), AA (50 ppm) and CCC (500 ppm) respectively (Yadava and Sreenath, 1975a).

Among all the major nutrients K is highly mobile monovalent cation indispensable to nutrition of higher plants within which it is the most abundant mineral elements. In addition it has been found that K may play an active part in turger of plant cells (Graham and Ulrich, 1972) as well as formation of organic acid (Smith, 1972). All these functions demonstrate the essentially of K for growth and development.

Tomer and Singh (1968) reported application of phosphorus to lucerne crop may be advantageous. Tanja *et. al.*, (1987), found that application at 80kg $P_2O_5$ / ha enhanced the seed yield as well as forage yield over the lower dose. It has been

reported by several workers that foliar application of $KNO_3$ 4kg/ha and super phosphate 1 kg/ha in cluster bean at pre-anthesis stage increased yield. Sinha (1984 b) found that in berseem, foliar application of 2kg $KNO_3$/ha + 2.5 kg/ha superphosphate with 60kg $P_2O_5$/ha as basal dose increased the seed yield. Rai (1981) found increase in seed yield over control in siratro, *S. gracilies, S. humilis* and Desmenthus virgatus was as 68.18%, 62.25% with 40kg $P_2O_5$, 45% and almost 300% with 60 kg $P_2O_5$ respectively.

In *Stylo* maximum seed yield was recorded by the application of DAP (4 Kg/ha) followed by DAP (6 Kg/ha), NAA (10 ppm) + K (2 Kg/ha) + DAP (2 Kg/ha), NAA (10 ppm) + K (2 Kg/ha), DAP (2 Kg/ha) + K (2 Kg/ha) and K (4 Kg/ha) however, the response of NAA treatment was at par. Over all the seed yield increased by 20- 25% in DAP + K treated plants. (Usha Yadav, 2000). The seed test weight also increased in all the treatments over the control and maximum seed test weight was recorded in DAP (2 Kg/ha) + K (2 Kg/ha) and DAP (4 Kg/ha) and (6 Kg/ha) (Usha Yadav, 2000). Foliar spray of phosphorous and nitrogen in the form of DAP, potassium in the form of muriate of potash and their combination with the NAA enhanced the level of photosynthetic pigments, nitrate reductase activity and soluble sugar through which the overall productivity of the crop improved. These studies clearly revealed that quality seed production in *Stylo* can be enhanced by the foliar application of DAP (4 Kg/ha) and DAP (2 Kg/ha) + K (2 Kg/ha) at vegetative and flower initiation stage.

# 3

# Materials and Methods

The proposed investigation was carried out on "*Physiological Analysis for Biomass Production and Seed Yield in Stylo*". The details of experimental sites, climatic conditions, choice of material and the methods applied have been described below.

## Experimental site

The experiment was conducted in experimental field of Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (U.P.) India (at the latitude $25.27^0$ N, longitude. $75.35^0$ E and an altitude of 275 meters above sea level) during the years 2002 and 2003. The soil of the experimental site was sandy loam. The soil contained nitrogen and organic carbon (0.34 %), available phosphorous (23 kg P/ha), potash (315 kg $K_2O$ /ha) and nearly neutral in reaction.

## Climatic conditions

The climatic conditions during the period of experimentation (2002 and 2003) is graphically presented in the figure 1. In 2002 the maximum temperature was ranged from 22.6 to 42.9 $^0$C and minimum temperature ranged from 5.6 to 28.0 $^0$C. During 2003 the maximum temperature was ranged from 20.4 to 42.9 $^0$C and minimum temperature ranged from 5.3 to 28.6 $^0$C. The average minimum and maximum temperature were 17.56 $^0$C and 33.13 $^0$C during 2002 and 17.63 $^0$C and 32.21 $^0$C during 2003 respectively. The total rainfall was 545.7 mm in 2002 and 1194.5 mm in 2003. In 2002 the total rainfall of 545.7 mm (January to December 2002) was received in 29 rainy days. This year onset of monsoon was late, arriving in the 32$^{nd}$ standard meteorological week (August 6-12) and remained effective up to 37$^{th}$ standard meteorological week (Sept 10-16). Good amount of rain 40.4 mm in 3 days was also received in the March 2002. In 2003 a total rainfall of 1194.5 mm was received in 38 rainy days. This year the onset of monsoon was in the 26$^{th}$ standard meteorological week (June, 25 – July 1$^{st}$) and continued up to 37$^{th}$ standard meteorological week (Sept. 10-16). In September, 732.3 mm rainfall in 11 rainy days was recorded, which is the highest ever received in this month. On 11$^{th}$ and 15$^{th}$ September a heavy amount of rainfall (167.4 mm and 183.2 mm, respectively) was received.

The relative humidity ranged from 50 % to 95 % in 2002 and 46% to 97% in 2003. The highest value of evaporation was recorded in May and minimum values in the month of Dec.-Jan. during both the years. The bright sunshine hours/day was recorded maximum in April during both the years.

## Choice of material

The genus stylo has been recognised for its adaptability and thus, has attracted many studies in different countries on its biology and utilization in the pastures. The genus *Stylosanthes* comprises to only 30 species but has provided more cultivars for tropical pasture than any other genus. The success of species

within this genus may be related to their rather distinctive morphology and to wide inter specific variation in morphological and physiological characteristics (Burt *et. al.*, 1980).

Looking wide adaptability and economic use of the *Stylosanthes,* the following studies were conducted:

## I. Growth, morphophysiological characters, seed yield and germination of different genotypes of *Stylosanthes*

### Plant Materials

The following twenty promising genotypes of *Stylosanthes* has been studied for their growth, morpho-physiology, biomass and seed yield in natural rainfed condition prevailing at IGFRI, Jhansi.

| | |
|---|---|
| *S. hamata* 110123 | *S. hamata* 110135 |
| *S. hamata* 61670 | *S. scabra* 36260 |
| *S. scabra* 93116, | *S. scabra* cv. *Fitzroy* |
| *S. scabra* cv. *S*eca | *S. scabra* q 10042 |
| *S. scabra*RRR 94-100 | *S. scabra* RRR 94-86 |
| *S. scabra* RRR 94-93 | *S. scabra* RRR 94-97 |
| *S. scabra* RRR 94-96 | *S. seabrana* 104710 |
| *S. seabrana* 105546 B | *S. seabrana* 110372 |
| *S. seabrana* 2523 | *S. seabrana* 2534 |
| *S. seabrana* 2539 | *S. viscosa* |

The experiment was laid out in the research field of Stylo Project at Central Research farm of Indian Grassland and Fodder Research Institute, Jhansi in plots (3 X 3 m) with three replication in Randomized Block Design. The healthy seeds of different genotypes of *Stylosanthes* was scarified by using sand paper and sown in the plot at 1 cm. depth at 25 cm row distance. Before sowing the soil samples

were taken for the analysis of nutrients status present in the soil. The plot were fertilized with basal dose of 20 kg N / hector and 40 kg $P_2O_5$ / hector. Potash was not applied, since the soil was rich in potassium content. After germination the weeding and inter-culturing was done at proper time during the growth of crop.

## II. Effect of foliar applied growth hormone and nutrients on flowering, seed setting, seed yield and quality of seeds in *Stylosanthes hamata*

The scarified seeds of *Stylosanthes hamata* were sown in rows at 25 cm distance in the plot size 4x 4 m with three replication in RBD. Basal dose of fertilizers i.e. 20 kg/ha N and 40 kg/ha P2O5 were applied before sowing of crops. The crop was raised as per recommended agronomical practices.

The treatments of following chemicals were imposed:

T1 - Control

T2 - Gibberellic acid ($GA_3$, 100 ppm)

T3 - Naphthalene acetic acid (NAA, 100 ppm)

T4 - $KNO_3$ (4 kg/ha)

T5 - Boron (100 ppm)

T6 - Cycocel (0.5 kg/ha)

The treatments were applied foliarly at vegetative stage (45 DAS) and flower initiation stage (80 DAS) of the plant. In the control plot crop was sprayed with water.

## Recording of observations

## Morpho-physiological parameters

The morphological parameters of plant such as plant height, number of branches, number of leaves, leaf area, root length, fresh and dry weight was recorded at 50% flowering stage.

For taking the fresh weight the plants were washed properly in running water and blotted to remove extra surface water before weighing.

The leaf area of fresh leaf was measured by using automatic portable leaf area meter (Model LI-3000, LICOR USA), before weighing.

The samples of each plant part were dried in an electric oven at 80 $^{0}$C for 48 hours and then the dry weight was recorded.

## Specific leaf weight (SLW)

The ratio of leaf dry weight (LDW) to leaf area (LA) was used for calculation of SLW:

$$SLW = \frac{\text{Leaf dry weight (LDW)}}{\text{Leaf area (LA)}} \quad (\text{mg cm}^{-2})$$

## Specific leaf area (SLA)

At the time of sampling SLA (leaf area/leaf dry weight) was measured by harvesting randomly 10 fully expanded leaves from each sample. Leaf area was measured with a leaf area meter and the leaves were oven dried at 80$^{0}$C for 48 h for dry weight measurement.

## Assimilatory characters

The physiological observations such as micro-environmental parameters, rate of photosynthesis (PN), stomatal conductance (CS), intercellular $CO_2$ concentration (CINT) and transpiration rate (TR) were recorded in the leaves using the LI – 6250 Portable photosynthesis system (LI-COR, USA). Photosynthetically active radiation (PAR), air temperature (AT), and relative humility (RH) were also measured during the recording of physiological observations. All the measurements were made at ambient $CO_2$ between 11.00 and 12.00 hour on a clear sky day. The ratio of PN/TR, PN/CINT was also calculated. Leaf transpiration was also measured at the time of recording these physiological observations. All these observations were made in fully expanded healthy second and third leaves of the plant.

## Chlorophyll accumulation

Chlorophyll a, b, and total chlorophyll contents was determined by extraction in dimethylsulfoxide (DMSO), following non – maceration technique of Hiscox and Israelstam (1979). Leaf slices weighing 50 mg were transferred to a test tube containing 5ml of DMSO. The tubes were then incubated in a hot air oven at $65^0$C for 2 hrs. They were taken out and absorbance read at 645 nm and 663 nm using a spectrophotometer (Digital spectrophotometer, ECIL, India). Chlorophyll content was calculated using the formula:

$$\text{Chl a} = [(12.7 \times O.D._{663}) - (2.69 \times O.D._{645})][V/(1000 \times W)]$$

$$\text{Chl b} = [(22.9 \times O.D._{645}) - (4.68 \times O.D._{663})][V/(1000 \times W)]$$

$$\text{Total Chlorophyll} = [(20.2 \times O.D._{645}) + (8.02 \times O.D._{663})][V/(1000 \times W)]$$

Where V =Volume of the extract

W =Weight of the leaf tissue taken

The chlorophyll content is expressed as mg /g f.w .

## Crude protein (CP)

Crude protein content in leaves was determined form the total nitrogen and multiplied by 6.25. Total nitrogen in plants was estimated by micro Kjeldahl method (A.O.A.C., 1960). 100 mg oven dried sample was taken in a dry micro Kjeldahl flask containing 5 ml $H_2SO_4$ (N free) and the catalytic mixture ($K_2SO_4$ and $CuSO_4$ in 5:1 ratio) and kept for digestion. The digested material was transferred into volumetric flask and volume made upto 50 ml. A suitable aliquot (5 ml) was taken into distillation apparatus along with 5-10 ml 40% NaOH. Ammonia was collected in 4% boric acid containing 2-3 drops of mixed indicator for 7-10 minutes and titrated with N/50 sulphuric acid solution.

$$\% \text{ Nitrogen} = \frac{\text{Sample tittered} - \text{Blank taken X Normality of } H_2SO_4}{\text{Sample weight}} \times 100$$

## Sugar content

Sugar content in the fresh leaves was estimated by using the phenolic methods. 1 gm fresh leaves were crushed in 200 ml distilled water in the Pestle and Mortar and mixed thoroughly. The charcoal was added to decolorize the solution. 1 ml of solution and 1 ml of distilled water was taken in the test tube and one drop of phenol was added in the tube. The test tubes were shacked properly and after shaking the tubes were kept in ice bath. 5.0 ml of sulfuric acid was added in each test tube by the side of test tube slowly. After colour development absorbance was taken at 520 nm. The sugar concentration was calculated from the standard curve of sugar.

## Nitrate Reductase Activity (NRA)

Nitrate Reductase Activity in fresh leaves was determined using methods of Bar-Akiva and Sternbaum (1965) and modified by Kleeper *et. al.,* (1971). Weighed 0.3 g. fresh leaves and cut into small pieces and placed in test tubes containing 3 ml. of 0.2 M $KNO_3$ and 3.0 ml of 0.1 M phosphate buffer (7.5 pH) and incubated for 60 minutes at 30-33 $^0$C. After one hour tubes were removed and immersed in boiling water bath for 4 minutes to stop the reaction for effective removal of nitrate accumulation in plant tissues. The tubes were cooled and 1.0 ml of 1% Nepthylene diamine hydrochloride added and mixed thoroughly and kept for 25 minutes for colour development. Subsequently 0.2 ml was taken in separate test tube and volume was made up to 6 ml with distilled water. Optical density was measured at 540 nm by using a Spectrophotometer (Digital spectrophotometer, ECIL, India) and Nitrate reductase activity was calculated from the optical density using standard curve and expressed in μ mole $NO_2$ /g/h of the fresh weight.

## Seed yield and yield contributing characters

To record seed yield, the crop was harvested at full maturation in the second weak of November during every year. After harvesting, plot wise seed crop was threshed properly and cleaned. The seed yield per plant and per hactare was recorded. For taking the seed test weight, thousand seeds of uniform size and colour were counted and seed weight was taken by using Electronic balance.

## Seed germination

The seeds of different genotypes of stylosanthes were harvested during December-January, 2003 were stored in polythine bags (700 gauge) at room temperature were taken for the germination study inAugust 2004. Since stylo seeds are having hard seed coat and therefore, the seeds require some dormancy breaking seed treatments for quick and better seed germination. Therefore the following seed treatments were given:

**Seed Treatments**

1) Control
2) $GA_3$ (300 ppm)
3) $KNO_3$ (0.2%)
4) Hot Water (60 $^0$C for 4 hours)
5) Conc. $H_2SO_4$ (for 5 minute and then washing in a running tap water)
6) Scarification.

25 seeds of each genotype were placed in each petriplate (6 cm. diameter) lined with 2 layer of filter paper moistened with distilled water. Three replications for each treatment were taken in this study.

Regular observations on seed germination, seedling length and vigour index were taken in the following manner

**(i) Seed germination percentage**

Daily germination was recorded for a period of 10 days and or till completion of germination. Germination percentage was given as calculated from the number of seeds germinated at the completion of germination in petriplates.

**(ii) Seedling elongation**

The seedling elongation was measured with the help of scale from the shoot tip of the seedling to the tip of the longest root after completion of germination. For taking seedling length ten seedlings was taken from each treatment and average seedling length was calculated.

**(iii) Vigour Index**

Vigour index was calculated by using the following formula:

Vigour Index (I) = Germination (%) X Seedling elongation

## Statistical analysis and presentation of data

The data were statistically analysed and significant response at 5% levels has been compiled by using the methods of Fisher and Yates (1963) and Panse and Sukhatma (1967). The necessary critical difference (CD) has been worked out for comparison of mean values of various treatments.

Correlation coefficient among various important morphological, physiological and biochemical parameters, assimilatory functions and seed yield were also worked out to establish and inter dependence of characters. Graphical representation has also been made to facilitate easy understanding of the table and responses on the observation.

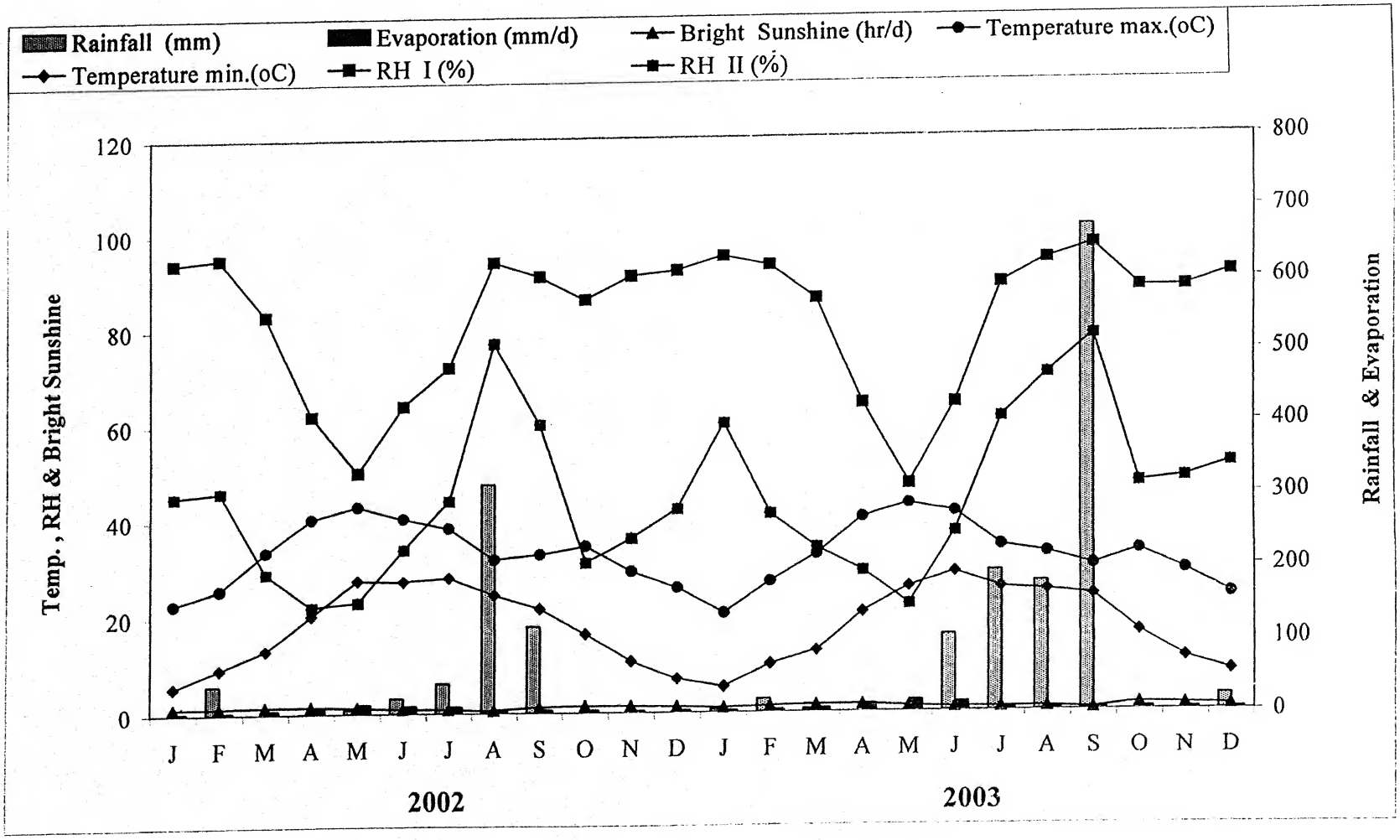


**Figure 1. Meteorological data during the year 2002 and 2003.**

# 4
# Results

## 4.1 Growth, morphophysiological characters, seed yield and germination in different genotypes of *Stylosanthes*.

### 4.1.1 Growth and Morphological characters

**a) Plant height**

The plant height of twenty genotypes of *Stylosanthes* during first and second years of growth is shown in table 1 and figure 2. The genotypic variation in plant height in different genotype of *Stylosanthes* ranged from 32.3 cm to 54.0 cm during the first year and 51.0 cm to 120.1 cm in the second year. On average of two years data the maximum height was recorded in *S. scabra* cv. *seca* followed by *S. seabrana* 110372 and minimum plant height was recorded *S. hamata* 110135. The plant height increment was higher in the genotypes of *S. scabra, S. seabrana* as compared to the genotype of *S. hamata*. However, *S. hamata* 61670, has shown faster growth in the second year as indicated by plant height increment. The genotypic variation was found statistically significant at P 0.05.

Table 1. Plant height and root length in different genotypes of *Stylosanthes*.

| Genotypes | Plant height (cm) | | | Root length (cm) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 50.30 | 51.20 | 50.75 | 19.90 | 23.40 | 21.65 |
| *S. hamata* 110135 | 43.60 | 51.00 | 47.30 | 18.50 | 17.10 | 17.80 |
| *S. hamata* 61670 | 47.00 | 73.60 | 60.30 | 22.30 | 28.90 | 25.60 |
| *S. scabra* 36260 | 42.00 | 89.83 | 65.91 | 22.20 | 25.10 | 23.65 |
| *S. scabra* 93116 | 51.60 | 93.80 | 72.70 | 25.10 | 28.10 | 26.60 |
| *S. scabra* cv. fitzroy | 47.00 | 113.30 | 80.15 | 23.80 | 27.80 | 25.80 |
| *S. scabra* cv. seca | 54.00 | 115.80 | 84.90 | 25.70 | 28.20 | 26.95 |
| *S. scabra* q 10042 | 52.60 | 99.70 | 76.15 | 25.90 | 30.20 | 28.05 |
| *S. scabra*RRR 94-100 | 53.60 | 108.4 | 81.00 | 25.50 | 27.60 | 26.55 |
| *S. scabra* RRR 94-86 | 48.30 | 100.60 | 74.45 | 17.90 | 20.90 | 19.40 |
| *S. scabra* RRR 94-93 | 42.30 | 89.80 | 66.05 | 19.40 | 19.60 | 19.50 |
| *S. scabra* RRR 94-97 | 42.30 | 94.40 | 68.35 | 23.50 | 24.60 | 24.05 |
| *S. scabra* RRR 94-96 | 51.30 | 106.20 | 78.75 | 23.10 | 24.10 | 23.60 |
| *S. seabrana* 104710 | 49.00 | 98.70 | 73.85 | 19.60 | 21.80 | 20.70 |
| *S. seabrana* 105546 B | 42.30 | 100.50 | 71.40 | 22.60 | 25.30 | 23.95 |
| *S. seabrana* 110372 | 48.60 | 120.10 | 84.35 | 26.70 | 34.50 | 30.60 |
| *S. seabrana* 2523 | 49.60 | 98.00 | 73.80 | 18.90 | 22.60 | 20.75 |
| *S. seabrana* 2534 | 44.30 | 103.70 | 74.00 | 20.40 | 22.10 | 21.25 |
| *S. seabrana* 2539 | 46.00 | 91.20 | 68.60 | 21.90 | 24.20 | 23.15 |
| *S. viscosa* | 32.30 | 71.00 | 51.50 | 18.90 | 28.80 | 23.85 |
| CD at 5% | 3.758 | 8.006 | - | N.S. | N.S. | - |

**Plate I. Growth performance of *Stylosanthes hamata.***

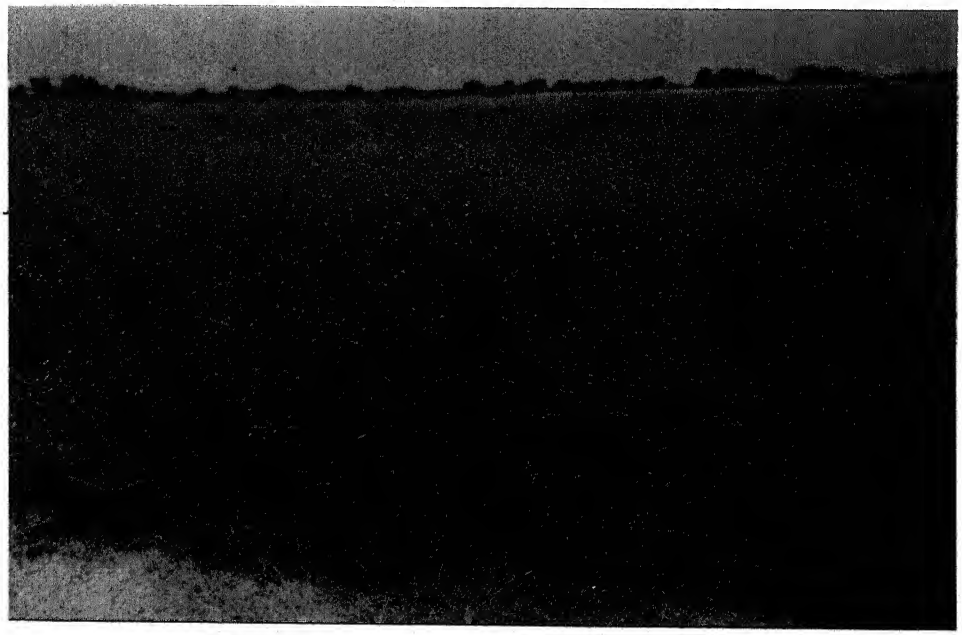

**Plate II. Growth performance of *Stylosanthes seabrana.***

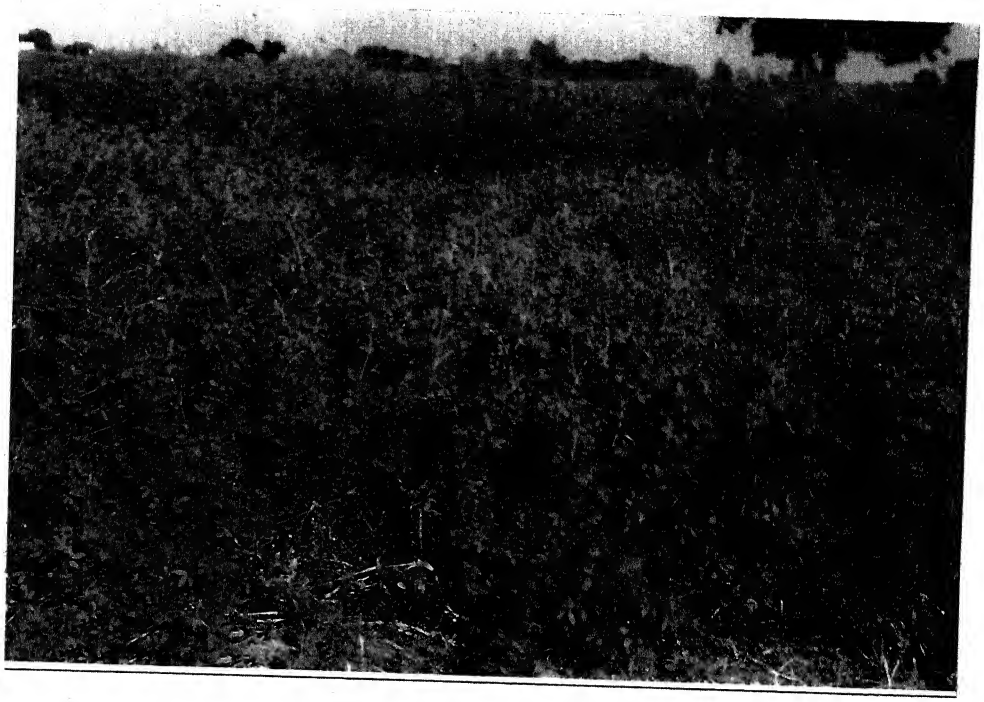

**Plate III. Growth performance of *Stylosanthes scabra.***

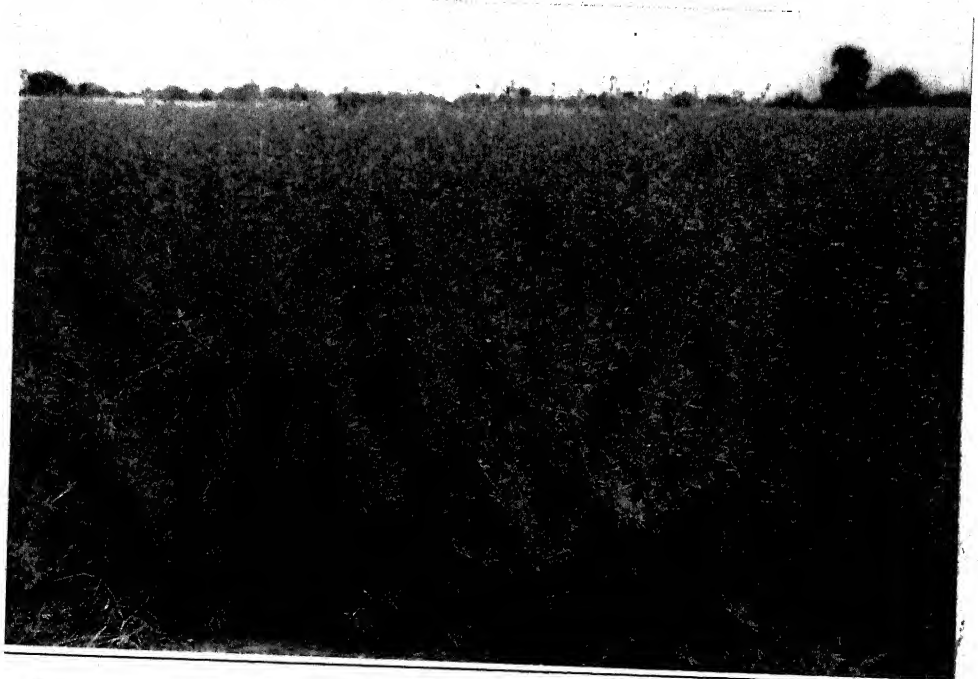

**Plate IV. Growth performance of *Stylosanthes viscosa.***

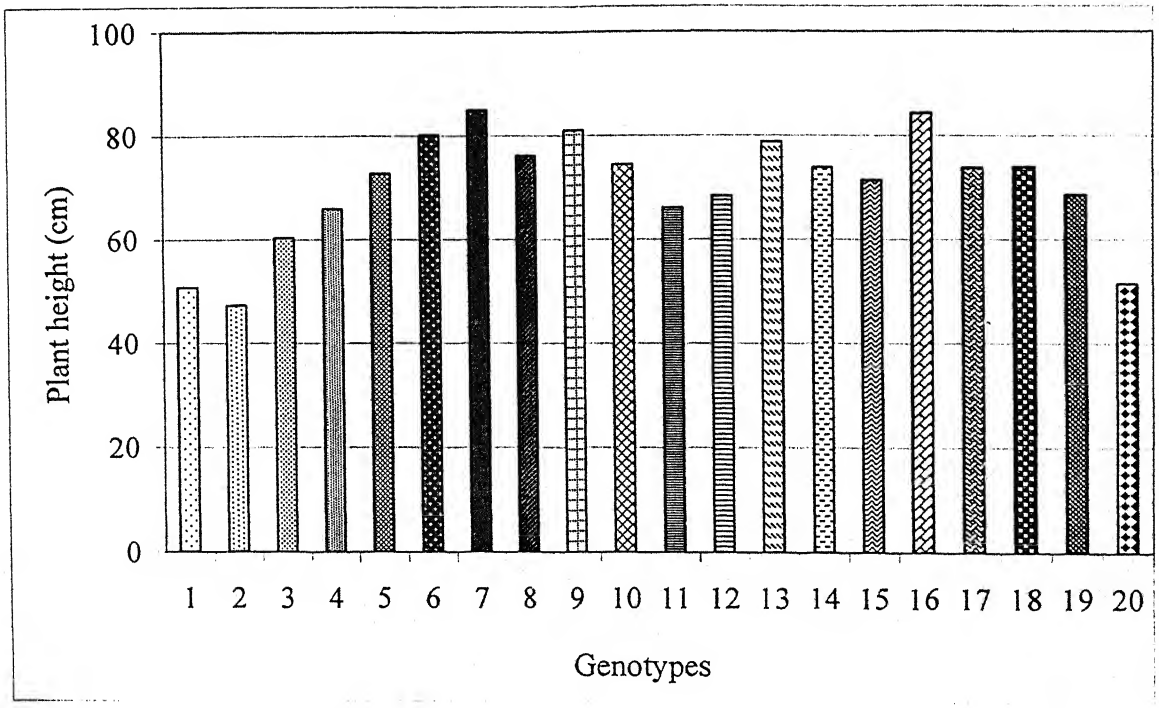


Figure 2. Plant height (cm) in different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

**b) Root Length**

The genotypic variation in the root length ranged from 17.9 to 26.7 cm in the first year and 17.1 cm to 34.5 cm in the second year. On average of two-year data the maximum root length was recorded in *S. seabrana* 110372 (30.6 cm) and minimum *S. hamata* 110135 (17.80 cm) (Table 1). More over maximum number of genotype were at par in their root length.

**c) Stem Diameter**

The stem diameter was recorded at 50% flowering growth stage and data are presented in table 2. Variability in stem thickness in term of stem diameter was also observed and it ranged from 0.35 cm to 0.68 cm in the first year and 0.62 to 1.50 cm in the second year of plant growth. On average of two years data the maximum stem diameter was recorded in *S. scabra* RRR 94-97 and *S. scabra* cv. Seca (0.79 cm) and minimum in *S. hamata* 110123 (0.51 cm). However, the genotypic variability in diameter growth was narrow in case of different genotypes of *S. scabra* and *S. seabrana.*

**d) Branch Number**

The branch production in term of branch number per plant was recorded in different genotypes of *Stylosanthes* at 50% flowering stage of the plant growth and no much variation was observed in the branch production per plant (Table 2). The branch number ranged from 13.0 (*S. seabrana* 2539) to 18.5 (*S. viscosa*). The genotypic difference in branch production was found non significant.

**e) Leaf length and width**

The leaf growth in term of length and width were measured and data presented in table 3. On average of two years data the leaf length varied from 1.95 cm (*S. viscosa*) to 3.10 cm in (*S. hamata* 110123). Similarly the variation in leaf width ranged from 0.5 cm. (*S. hamata* 110135) to 1.20 cm (*S. scabra* RRR 94-97). The genotypic variability in leaf width was higher as compared to the leaf length. The genotypic variation in leaf length and leaf width was statistically significant at P 0.05.

Table 2. Stem diameter and branch number per plant in different genotypes of *Stylosanthes*.

| Genotypes | Stem diameter (cm) | | | Branch number/Plant | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 0.41 | 0.62 | 0.51 | 18.00 | 16.00 | 17.00 |
| *S. hamata* 110135 | 0.42 | 0.70 | 0.56 | 15.00 | 17.00 | 16.00 |
| *S. hamata* 61670 | 0.40 | 1.00 | 0.70 | 14.00 | 13.00 | 13.50 |
| *S. scabra* 36260 | 0.38 | 1.10 | 0.69 | 16.00 | 16.00 | 16.00 |
| *S. scabra* 93116 | 0.40 | 1.00 | 0.70 | 14.00 | 16.00 | 15.00 |
| *S. scabra* cv. Fitzroy | 0.49 | 1.30 | 0.76 | 18.00 | 15.00 | 16.50 |
| *S. scabra* cv. Seca | 0.39 | 1.20 | 0.79 | 13.00 | 16.00 | 14.50 |
| *S. scabra* q 10042 | 0.42 | 1.30 | 0.72 | 17.00 | 17.00 | 17.00 |
| *S. scabra* RRR94-100 | 0.53 | 1.20 | 0.77 | 15.00 | 16.00 | 15.50 |
| *S. scabra* RRR 94-86 | 0.50 | 1.10 | 0.75 | 16.00 | 16.00 | 16.00 |
| *S. scabra* RRR 94-93 | 0.51 | 1.30 | 0.77 | 17.00 | 15.00 | 16.00 |
| *S. scabra* RRR 94-97 | 0.68 | 0.90 | 0.79 | 16.00 | 19.00 | 17.50 |
| *S. scabra* RRR 94-96 | 0.49 | 1.40 | 0.76 | 17.00 | 16.00 | 16.50 |
| *S. seabrana* 104710 | 0.46 | 1.50 | 0.75 | 14.00 | 14.00 | 14.00 |
| *S. seabrana* 105546 B | 0.38 | 1.40 | 0.71 | 14.00 | 17.00 | 15.50 |
| *S. seabrana* 110372 | 0.35 | 1.10 | 0.68 | 12.00 | 16.00 | 14.00 |
| *S. seabrana* 2523 | 0.42 | 1.00 | 0.71 | 15.00 | 17.00 | 16.00 |
| *S. seabrana* 2534 | 0.46 | 1.20 | 0.74 | 12.00 | 16.00 | 14.00 |
| *S. seabrana* 2539 | 0.49 | 1.10 | 0.75 | 11.00 | 15.00 | 13.00 |
| *S. viscose* | 0.50 | 0.90 | 0.70 | 19.00 | 18.00 | 18.50 |
| CD at 5% | 0.051 | 0.130 | - | N.S. | N.S. | - |

Table 3. Leaf length and leaf width in different genotypes of *Stylosanthes*.

| Genotypes | Leaf length (cm) | | | Leaf width (cm) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 2.70 | 3.50 | 3.10 | 0.60 | 0.50 | 0.55 |
| *S. hamata* 110135 | 2.30 | 3.50 | 2.90 | 0.50 | 0.50 | 0.50 |
| *S. hamata* 61670 | 2.50 | 2.80 | 2.65 | 0.80 | 0.70 | 0.75 |
| *S. scabra* 36260 | 2.00 | 2.50 | 2.25 | 0.70 | 0.80 | 0.75 |
| *S. scabra* 93116 | 1.80 | 2.80 | 2.30 | 0.70 | 0.70 | 0.70 |
| *S. scabra* cv. Fitzroy | 2.20 | 2.80 | 2.50 | 1.20 | 1.10 | 1.15 |
| *S. scabra* cv. Seca | 2.20 | 2.80 | 2.50 | 1.20 | 1.00 | 1.10 |
| *S. scabra* q 10042 | 2.30 | 3.20 | 2.75 | 0.90 | 1.10 | 1.00 |
| *S. scabra*RRR 94-100 | 2.20 | 2.30 | 2.25 | 1.10 | 1.00 | 1.05 |
| *S. scabra*RRR 94-86 | 2.60 | 2.50 | 2.55 | 1.10 | 1.00 | 1.05 |
| *S. scabra* RRR 94-93 | 2.10 | 2.50 | 2.30 | 0.90 | 0.80 | 0.85 |
| *S. scabra* RRR 94-97 | 2.70 | 2.20 | 2.45 | 1.30 | 1.10 | 1.20 |
| *S. scabra* RRR 94-96 | 2.40 | 2.70 | 2.55 | 0.80 | 0.90 | 0.85 |
| *S. seabrana* 104710 | 1.80 | 2.70 | 2.25 | 0.50 | 0.60 | 0.55 |
| *S. seabrana* 105546 B | 1.90 | 3.00 | 2.45 | 1.00 | 1.00 | 1.00 |
| *S. seabrana* 110372 | 1.80 | 2.40 | 2.10 | 0.90 | 1.20 | 1.05 |
| *S. seabrana* 2523 | 1.70 | 2.60 | 2.15 | 0.60 | 0.70 | 0.65 |
| *S. seabrana* 2534 | 2.00 | 2.80 | 2.40 | 0.60 | 0.70 | 0.65 |
| *S. seabrana* 2539 | 2.20 | 2.40 | 2.30 | 0.70 | 0.60 | 0.65 |
| *S. viscose* | 1.80 | 2.10 | 1.95 | 0.90 | 1.00 | 0.95 |
| CD at 5% | 0.190 | 0.194 | _ | 0.140 | 0.098 | _ |

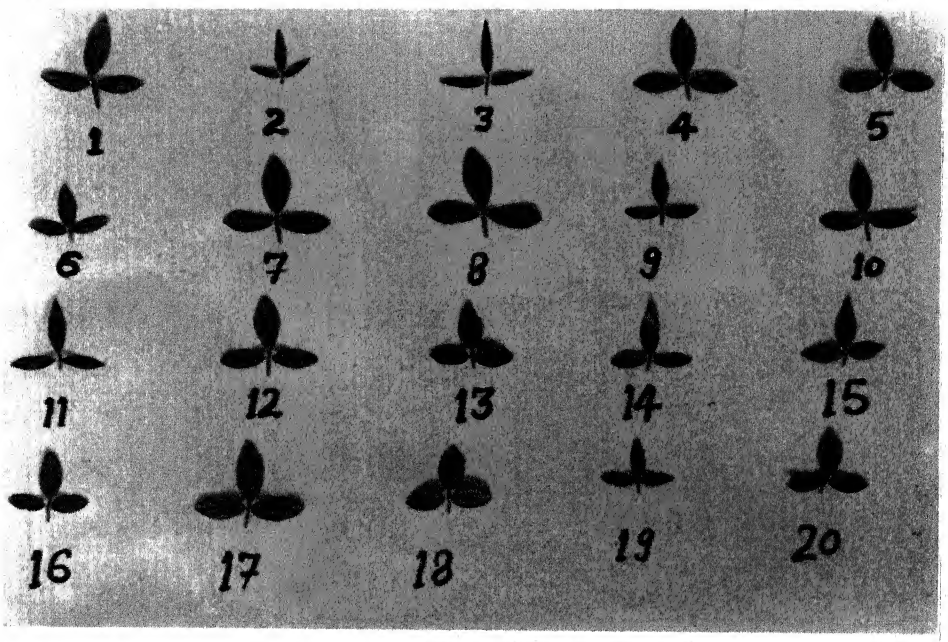


**Plate V. Variation in leaf shape and size in various genotypes of *Stylosanthes*.**

## 4.1.2: Physiological characters

### a) Biomass accumulation

### i) Fresh weight

Total biomass production in term of fresh weight per plant at 50% flowering stage in all genotypes is shown in table 4, 6 and figure 3. The fresh biomass production per plant ranged from 47.96 gm (*S. hamata* 110123) to 93.38 gm (*S. scabra* q 10042) in the first year while in the second year the maximum biomass production was observed in *S. scabra* RRR 94-100 (756.29 gm/plant). On average of two years data the maximum fresh biomass accumulation was observed in *S. scabra* RRR 94-100 followed by *S. scabra* q 10042 and minimum in *S. hamata* 110123. Similarly in root the higher biomass accumulation was observed in *S. sacbra* q 10042 (24.04 gm/plant) and lowest in *S. hamata* 110123 (3.84 gm/plant). The biomass accumulation during the second year in all the genotypes of *Stylosanthes* was much higher than the first year, which may be due to regeneration of the same plant, which was harvested, in the first year. This has also indicated that the biomass production potential of each genotypes after regeneration in the second year. Looking in to the data as presented in table 4,6 and figure 3 large variability exist in the *Stylosanthes* germplasm. The data were statistically significant. Total fresh biomass (above ground + below ground) is shown in table 6. On average of two years data the maximum shoot biomass was observed in *S. scabra* RRR 94-100 (421.98 gm/plant) and minimum in *S. hamata* 110123 (87.31 gm/plant).

Table 4. Fresh biomass production in different genotypes of *Stylosanthes*.

| Genotypes | Shoot (gm/plant) | | | Root (gm/plant) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 45.88 | 121.07 | 83.28 | 2.08 | 5.60 | 3.84 |
| *S. hamata* 110135 | 68.96 | 253.90 | 161.25 | 3.65 | 5.70 | 4.67 |
| *S. hamata* 61670 | 70.71 | 205.48 | 137.74 | 3.85 | 5.88 | 4.86 |
| *S. scabra* 36260 | 59.61 | 296.20 | 177.70 | 3.46 | 10.41 | 6.93 |
| *S. scabra* 93116 | 57.49 | 270.17 | 163.28 | 3.22 | 9.31 | 6.26 |
| *S. scabra* cv. fitzroy | 52.23 | 243.20 | 147.70 | 3.10 | 7.50 | 5.30 |
| *S. scabra* cv. seca | 56.90 | 426.90 | 241.90 | 3.12 | 17.03 | 10.07 |
| *S. scabra* q 10042 | 89.20 | 622.30 | 355.75 | 4.18 | 43.90 | 24.04 |
| *S. scabra*RRR 94-100 | 83.23 | 738.50 | 410.90 | 4.45 | 17.79 | 11.12 |
| *S. scabra* RRR 94-86 | 61.46 | 313.79 | 187.74 | 3.62 | 21.29 | 12.45 |
| *S. scabra* RRR 94-93 | 72.33 | 411.70 | 241.95 | 3.98 | 10.04 | 7.01 |
| *S. scabra* RRR 94-97 | 64.60 | 589.27 | 326.93 | 3.72 | 24.31 | 14.01 |
| *S. scabra* RRR 94-96 | 56.60 | 556.30 | 306.30 | 3.12 | 30.81 | 16.96 |
| *S. seabrana* 104710 | 48.46 | 274.50 | 162.06 | 2.15 | 11.14 | 6.64 |
| *S. seabrana* 105546 B | 53.53 | 353.26 | 203.48 | 2.86 | 9.53 | 6.19 |
| *S. seabrana* 110372 | 57.93 | 422.30 | 239.95 | 2.95 | 14.80 | 8.87 |
| *S. seabrana* 2523 | 58.23 | 171.30 | 113.25 | 2.92 | 14.23 | 8.57 |
| *S. seabrana* 2534 | 56.33 | 302.39 | 179.34 | 2.88 | 10.43 | 6.65 |
| *S. seabrana* 2539 | 58.36 | 318.69 | 188.69 | 2.90 | 14.64 | 8.77 |
| *S. viscosa* | 53.77 | 276.71 | 165.25 | 2.78 | 15.50 | 9.14 |
| CD at 5% | 2.431 | 65.360 | - | 0.198 | 2.866 | - |

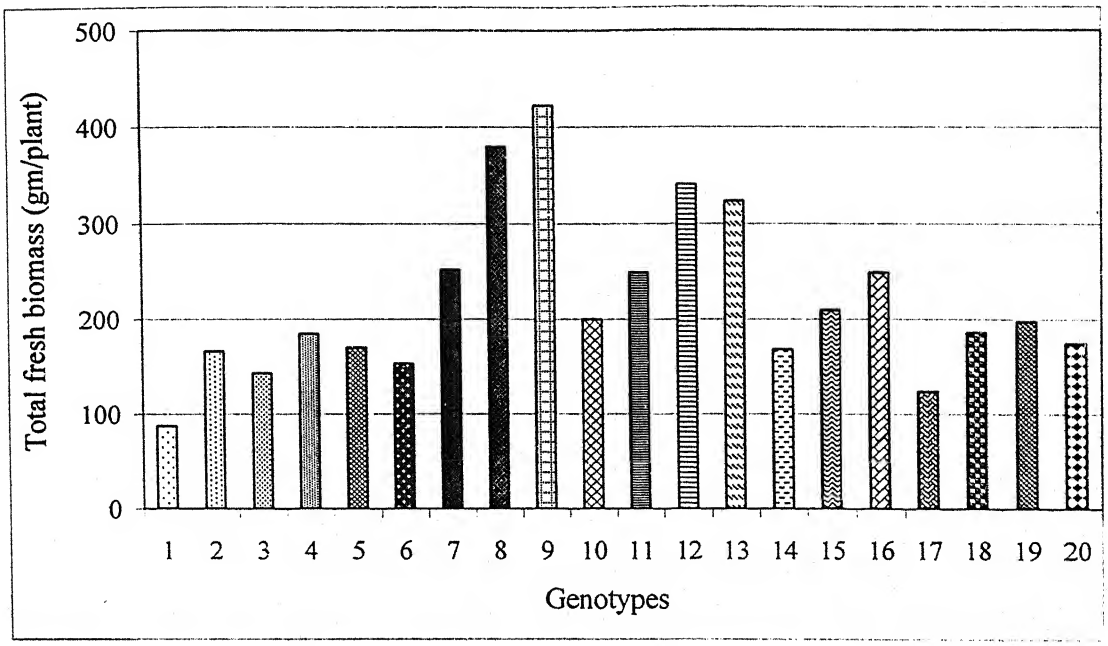


Figure 3. Total fresh biomass in different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *f*itzroy, 7. *S. scabra* cv. *s*eca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

**ii) Dry weight**

The total biomass production per plant in term of dry weight in different genotypes is shown in table 5,6 and figure 4. Similar to the fresh weight, the maximum dry matter production was recorded in *S. scabra* RRR 94-100 (176.47 gm./plant) followed *S. scabra* q 10042 (171.95 gm./plant) and minimum dry weight was recorded in *S. hamata* 110123 (29.32 gm./plant) (Table 6). In the first year the dry matter yield per plant was ranged from 16.40 to 31.93 gm./plant where as in the second year the dry matter yield per plant ranged from 42.24 gm to 321.02. The total dry matter yield during the second year was much higher than the first year which may be again due to the regeneration of the first year harvested plants in the second year. The dry matter production in shoot and root is

also recorded and data presented in table 5. Similar to the total dry biomass the maximum shoot biomass was recorded in *S. scabra* RRR 94-100 followed by *S. scabra* q 10042 and minimum in *S. hamata* 110123. The root dry weight was recorded maximum in *S. scabra* q 10042 and lowest in *S. hamata* 110123. As apparent from the data large genotypic variability exists in the shoot and root dry matter accumulation in *Stylosanthes* germplasm. The data were statistically significant.

**b) Partitioning of Dry matter**

The partitioning of dry matter in above ground parts (shoots and leaves) and below ground parts i.e. in roots in all the genotypes is given in figure 5. The Dry matter partitioning was maximum in above ground parts and minimum in roots in all the genotypes of *Stylosenthes*. On average of two years data the biomass partitioning in above ground parts ranged from 92.20% to 95.70%. As apparent from the data that variation in partitioning of biomass in above ground parts is not significant among the genotypes of *Stylosenthes* where as in roots the variability ranged from 4.30 to 7.78%. The partitioning of biomass in above ground part was higher during the second year as compared to the first year. In most of the genotypes the partitioning of biomass in roots was lower as compared to the first year which may be due to the more foliage production during the second year after regeneration. The maximum biomass partitioning was observed in shoot and leaves in *S. seabrana* 105546B where as the maximum partitioning of biomass in root was recorded in *S. seabrana* 104710 followed by *S. seabrana* 2523.

Table 5. Dry matter yield in shoot and root of different genotypes of *Stylosanthes.*

| Genotypes | Shoot (g/plant) | | | Root (g/plant) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 15.21 | 39.48 | 27.34 | 1.19 | 2.76 | 1.98 |
| *S. hamata* 110135 | 23.01 | 91.96 | 57.48 | 1.75 | 2.72 | 2.24 |
| *S. hamata* 61670 | 24.77 | 100.02 | 62.39 | 1.87 | 3.18 | 2.53 |
| *S. scabra* 36260 | 21.36 | 171.78 | 96.57 | 1.59 | 6.12 | 3.86 |
| *S. scabra* 93116 | 21.39 | 132.63 | 77.01 | 1.48 | 5.20 | 3.34 |
| *S. scabra* cv. fitzroy | 20.80 | 110.28 | 65.54 | 1.43 | 4.80 | 3.12 |
| *S. scabra* cv. seca | 19.32 | 129.36 | 74.34 | 1.44 | 6.16 | 3.80 |
| *S. scabra* q 10042 | 29.75 | 293.63 | 161.69 | 1.92 | 18.60 | 10.26 |
| *S. scabra*RRR 94-100 | 29.88 | 312.40 | 171.14 | 2.05 | 8.63 | 5.34 |
| *S. scabra* RRR 94-86 | 19.98 | 162.57 | 91.27 | 1.67 | 10.24 | 5.95 |
| *S. scabra* RRR 94-93 | 25.78 | 168.24 | 97.01 | 1.83 | 6.58 | 4.20 |
| *S. scabra* RRR 94-97 | 22.56 | 279.76 | 151.17 | 1.71 | 11.64 | 6.68 |
| *S. scabra* RRR 94-96 | 18.64 | 276.42 | 147.53 | 1.44 | 15.10 | 8.27 |
| *S. seabrana* 104710 | 18.12 | 152.73 | 85.42 | 1.01 | 17.54 | 9.28 |
| *S. seabrana* 105546 B | 19.96 | 137.67 | 78.81 | 1.34 | 3.28 | 2.31 |
| *S. seabrana* 110372 | 20.47 | 201.55 | 111.01 | 1.38 | 7.83 | 4.61 |
| *S. seabrana* 2523 | 18.67 | 97.70 | 58.18 | 1.37 | 7.58 | 4.48 |
| *S. seabrana* 2534 | 19.92 | 125.28 | 72.60 | 1.35 | 4.36 | 2.86 |
| *S. seabrana* 2539 | 20.70 | 124.29 | 72.49 | 1.36 | 7.45 | 4.41 |
| *S. viscosa* | 18.80 | 109.85 | 64.32 | 1.33 | 7.61 | 4.47 |
| CD at 5% | N.S. | 17.575 | - | 0.009 | 1.162 | - |

Table 6. Total fresh biomass and total dry biomass in different genotypes of *Stylosanthes*.

| Genotypes | Total fresh biomass (g/plant) | | | Total dry biomass (g/plant) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 47.96 | 126.67 | 87.31 | 16.40 | 42.24 | 29.32 |
| *S. hamata* 110135 | 72.61 | 259.60 | 166.10 | 24.76 | 94.68 | 59.72 |
| *S. hamata* 61670 | 74.56 | 211.36 | 142.96 | 26.64 | 103.20 | 64.83 |
| *S. scabra* 36260 | 63.07 | 306.61 | 184.84 | 22.95 | 177.90 | 100.42 |
| *S. scabra* 93116 | 60.71 | 279.48 | 170.09 | 22.87 | 137.83 | 80.35 |
| *S. scabra* cv. fitzroy | 55.33 | 250.70 | 153.01 | 22.23 | 115.08 | 68.65 |
| *S. scabra* cv. seca | 60.02 | 443.93 | 251.97 | 20.76 | 135.52 | 78.14 |
| *S. scabra* q 10042 | 93.38 | 666.20 | 379.79 | 31.67 | 312.23 | 171.95 |
| *S. scabra*RRR 94-100 | 87.68 | 756.29 | 421.98 | 31.93 | 321.02 | 176.47 |
| *S. scabra* RRR 94-86 | 65.08 | 335.08 | 200.08 | 21.65 | 172.81 | 102.23 |
| *S. scabra* RRR 94-93 | 76.31 | 421.74 | 249.05 | 27.61 | 174.82 | 101.21 |
| *S. scabra* RRR 94-97 | 68.32 | 613.51 | 340.91 | 24.27 | 291.40 | 157.83 |
| *S. scabra* RRR 94-96 | 59.72 | 587.11 | 323.41 | 20.08 | 291.52 | 155.80 |
| *S. seabrana* 104710 | 50.61 | 285.64 | 168.12 | 19.13 | 170.27 | 94.70 |
| *S. seabrana* 105546 B | 56.39 | 362.79 | 209.59 | 21.30 | 140.90 | 81.10 |
| *S. seabrana* 110372 | 60.88 | 437.10 | 248.99 | 21.85 | 209.33 | 115.59 |
| *S. seabrana* 2523 | 61.15 | 155.83 | 123.34 | 20.04 | 105.28 | 62.66 |
| *S. seabrana* 2534 | 59.21 | 312.82 | 186.01 | 21.27 | 129.64 | 75.45 |
| *S. seabrana* 2539 | 61.26 | 333.33 | 197.29 | 22.06 | 131.74 | 76.90 |
| *S. viscosa* | 56.55 | 292.21 | 174.38 | 20.13 | 117.46 | 68.79 |
| CD at 5% | 0.68 | 0.48 | - | 0.63 | 0.008 | - |

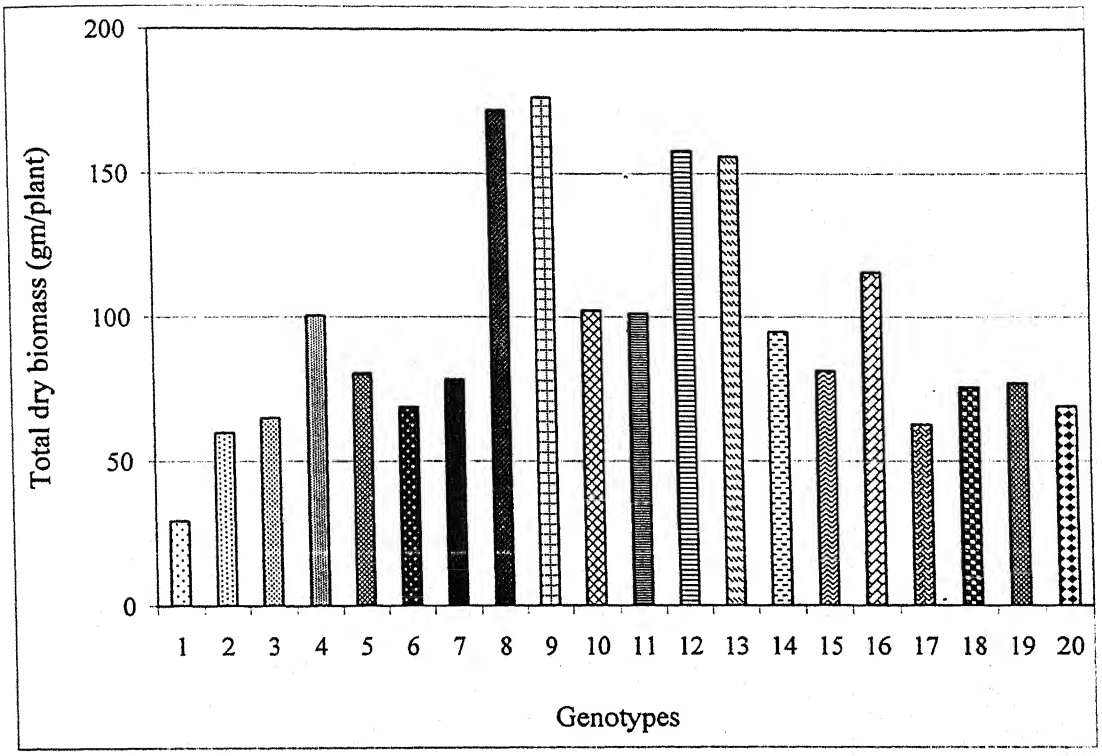


Figure 4. Total dry biomass (gm) in different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

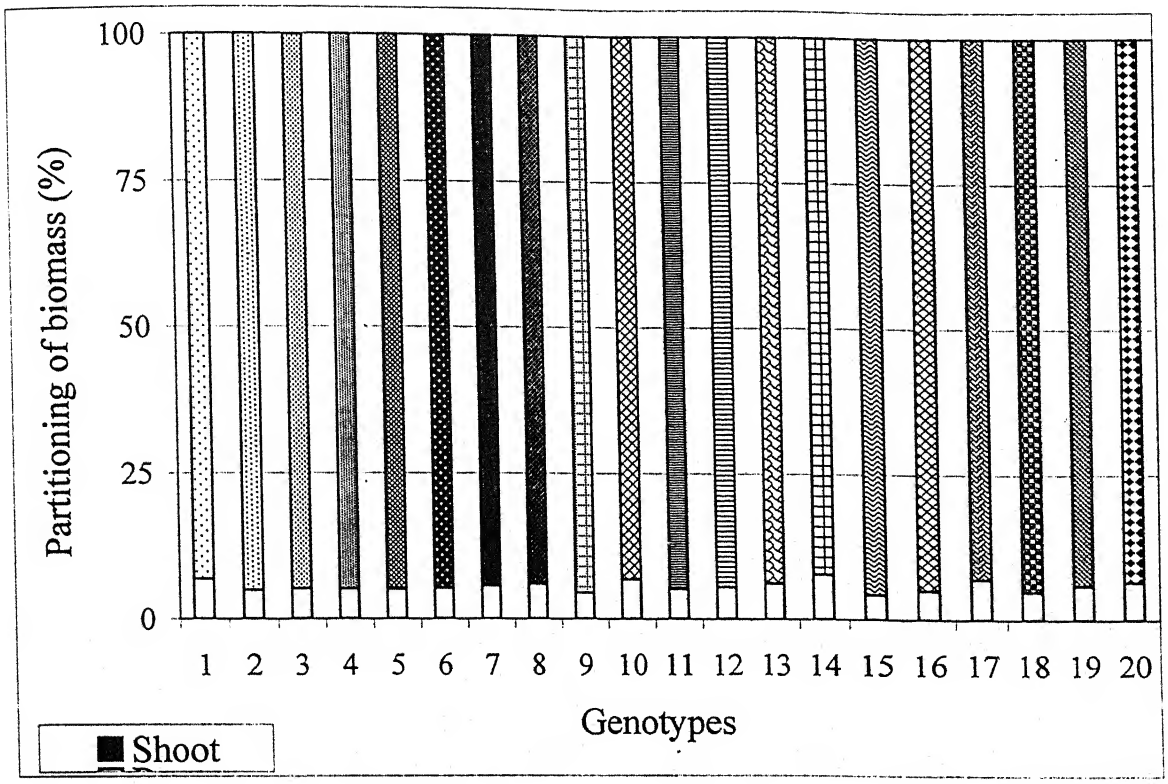


Figure 5. Partitioning of above and below ground biomass (%) in different genotypes of *Stylosanthes*.
(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

**c) Leaf area**

Leaf area per leaf was recorded at 50 % flowering stage in all the genotypes and shown in table 7. On average of two years data the leaf area ranged from 2.22 (*S seabrana* 2523) to 3.87 $cm^2$ in *S. scabra* q 10042. In the first year maximum leaf area per leaf was recorded in *S. scabra* cv seca (3.99 $cm^2$) and *S. scabra* q 10042 (3.93 $cm^2$) and minimum in *S. seabrana* 2523 (2.07 $cm^2$) where as during the second year the maximum leaf area was observed in *S. scabra* q 10042 and minimum in *S. seabrana* 2534.

Table 7. Variation in leaf area per leaf in different genotypes of *Stylosanthes.*

| Genotypes | Leaf area ($cm^2$ / leaf) | | |
|---|---|---|---|
| | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 2.74 | 3.09 | 2.92 |
| *S. hamata* 110135 | 2.21 | 2.81 | 2.51 |
| *S. hamata* 61670 | 2.43 | 3.06 | 2.75 |
| *S. scabra* 36260 | 2.23 | 2.90 | 2.57 |
| *S. scabra* 93116 | 2.25 | 2.55 | 2.40 |
| *S. scabra* cv. Fitzroy | 3.36 | 3.18 | 3.27 |
| *S. scabra* cv. Seca | 3.99 | 3.04 | 3.52 |
| *S. scabra* q 10042 | 3.93 | 3.82 | 3.87 |
| *S. scabra*RRR 94-100 | 3.34 | 2.97 | 3.16 |
| *S. scabra* RRR 94-86 | 3.41 | 3.36 | 3.39 |
| *S. scabra* RRR 94-93 | 3.15 | 3.38 | 3.26 |
| *S. scabra* RRR 94-97 | 3.68 | 3.44 | 3.56 |
| *S. scabra* RRR 94-96 | 2.84 | 3.43 | 3.13 |
| *S. seabrana* 104710 | 2.17 | 2.35 | 2.26 |
| *S. seabrana* 105546 B | 3.11 | 3.29 | 3.20 |
| *S. seabrana* 110372 | 3.01 | 2.95 | 2.98 |
| *S. seabrana* 2523 | 2.07 | 2.40 | 2.22 |
| *S. seabrana* 2534 | 2.65 | 2.28 | 4.47 |
| *S. seabrana* 2539 | 2.18 | 2.45 | 2.31 |
| *S. viscosa* | 2.46 | 2.34 | 2.40 |
| CD at 5% | 0.294 | 0.195 | - |

**d) Specific leaf weight**

The specific leaf weight (SLW) which represents the accumulations of dry matter in per unit leaf area of all the genotypes is given in figure 6. On average of two years data the specific leaf weight ranged from 4.86 mg/cm$^2$ to 9.44 mg/cm$^2$. Maximum specific leaf weight was recorded in *S. scabra* RRR 94-100, followed by *S. scabra* q 10042, *S. sesbrana* 2539 and lowest SLW was observed in *S. hamata* 110123. As apparent from the data the variability exits in different genotypes. Looking the species variation with respect to SLW the genotype *S. scabra* have the maximum followed by genotype of *S. seabrana* and minimum in the genotype of *S. hamata.*

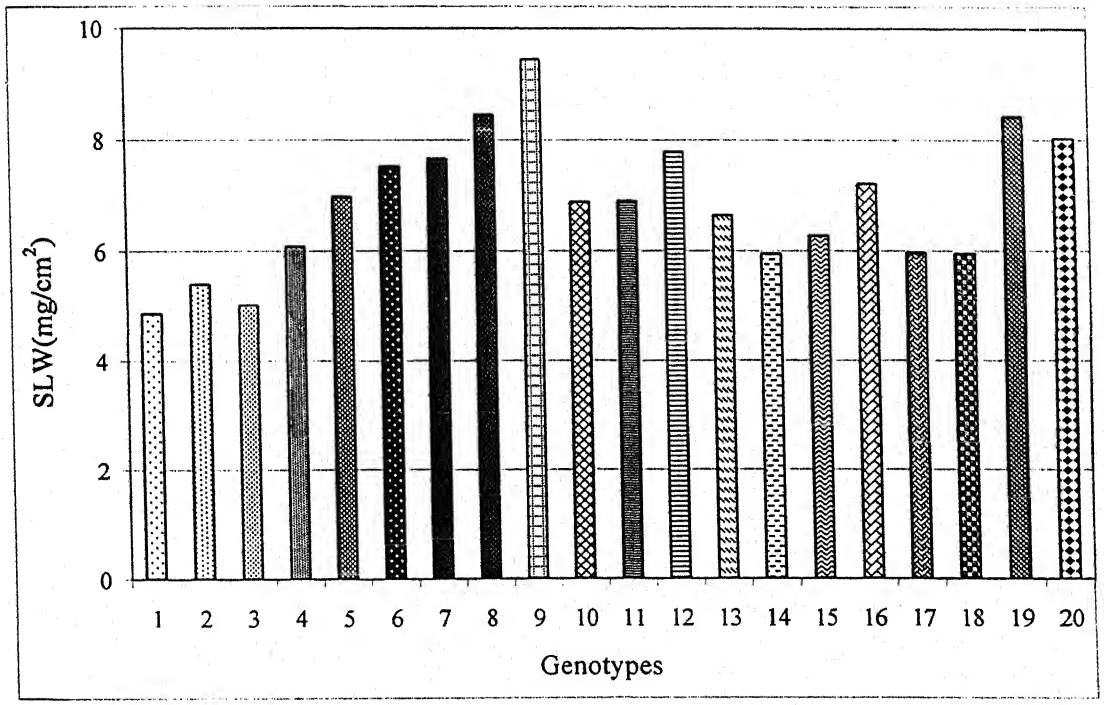


Figure 6. Variation in specific leaf weight (SLW) in different genotypes of *Stylosanthes.*

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

## e) Specific leaf area

Specific leaf area (SLA) which represents unit leaf area production per unit leaf dry weight accumulation is given in figure 7. The variability in the specific leaf area ranged from 100 to 210 ($cm^2$/mg). The maximum SLA was observed in *S. scabra* 36260 followed by *S. hamata.* The minimum SLA was observed in *S. scabra* RRR 94-100. However, maximum number of genotypes of *S. scabra* and *S. seabrana* were at par in their specific leaf area.

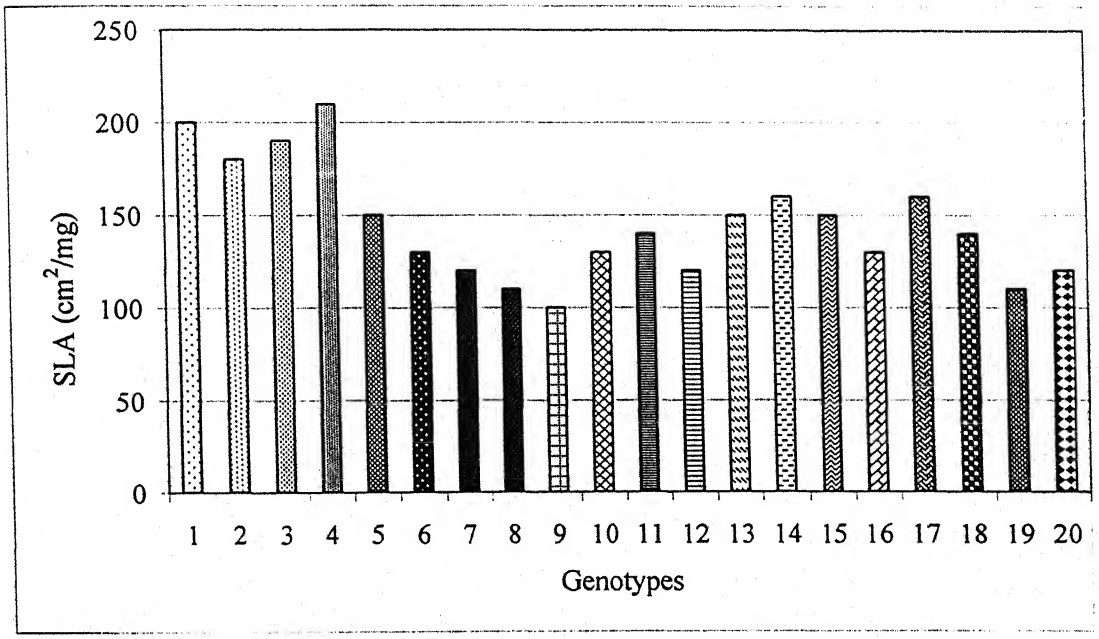


Figure 7. Variation in specific leaf area (SLA) in different genotypes of *Stylosanthes.*

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

## 4.1.3. Assimilatory Characters

### 1. Micro environmental parameters

The micro environmental parameters viz., relative humidity (RH), Air temperature (AT) and Photosynthetically Active Radiation (PAR) were recorded at the time of recording assimilatory functions such as rate of photosynthesis (PN), rate of transpiration (TR), stomatal conductance (Cs) and intercellular carbon dioxide concentration (CINT) during the noon hours on clear sky day. The mean value of both the years of these micro environmental parameters is shown figure 8. The RH ranged from 32.52% to 36.53%, air temperature ranged from 31.46 $^0$C to 33.70 $^0$C and PAR ranged from 1218 to 1295 μ mole / $m^2$ /s. These are the main micro environmental parameters which influences the functional behavior of the genotypes.

### 2. Leaf temperature

The leaf temperature was also recorded at the time of recording assimilatory parameters of the leaves and shown in table 10. The leaf temperature ranged 30 $^0$C to 33.68 $^0$C and 31.84 $^0$C to 34.57 $^0$C in the first and second year respectively. On average of both the years, leaf temperature of different genotype ranged from 30.99 $^0$C to 34.12 $^0$C. This has indicated that the leaf temperature is genotypic dependence.

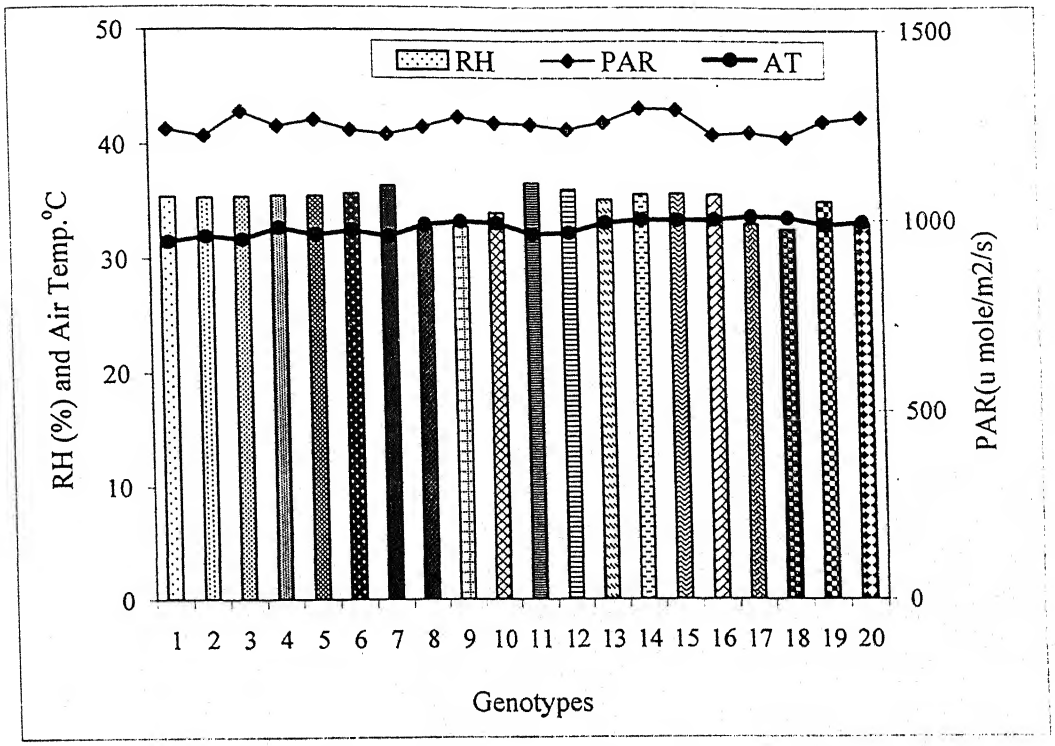


Figure 8. Micro environmental parameters in different genotypes of *Stylosanthes* (Average of two year data).

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

### 3. Photosynthesis

Genotypic variation in the rate of net photosynthesis (PN) in all the genotypes is given in table 8 and figure 9. The rate of photosynthesis in different genotypes ranged from 19.65 μ mole/$m^2$/s to 27.67 μ mole/$m^2$/s. On average of two years data maximum rate of photosynthesis was recorded in *S. scabra* cv seca (27.67 μ mole /$m^2$/s) followed by *S. scabra* RRR 94-93 (26.12 μ mole/$m^2$/s) and minimum in *S. hamata* 110135 (19.65μ mole/$m^2$/s). In the first year similar trend was observe but during the second year higher

rate of photosynthesis was recorded in *S.seaberna* 2534 (28.01μ mole/$m^2$/s) which were at par to the photosynthetic rate of *S. scabra* cv seca (28.66μ mole/$m^2$/s). However, most of the genotypes were at par in their rate of photosynthesis. The genotypic difference were statistically significant (P 0.05).

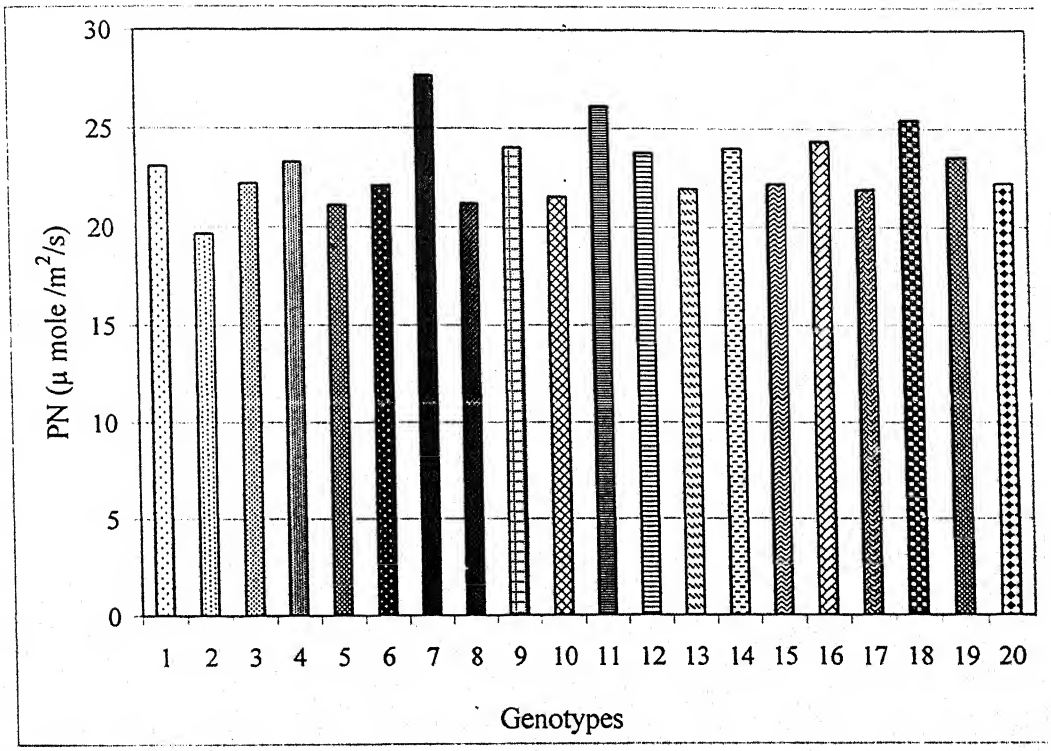


Figure 9. Rate of photosynthesis in different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

## 4. Transpiration

Rate of transpiration in all the genotypes is shown in table 8 and figure 10. As apparent from data the transpiration rate ranged from 8.40 m mole/$m^2$/s to 13.33 m mole/$m^2$/s. The maximum rate of transpiration was recorded in *S. scabra* RRR 94-93 followed by *S. seabrana* 110372 which were at par to *S. scabra* 93116 and minimum in *S. hamata* (Diploid) 61670. Trend in the rate of transpiration in different genotype during first and second year was similar. Genotypic variability in the rate of transpiration was maximum in the genotypes of *S. scabra* as compared to the *S. seabrana* genotypes.

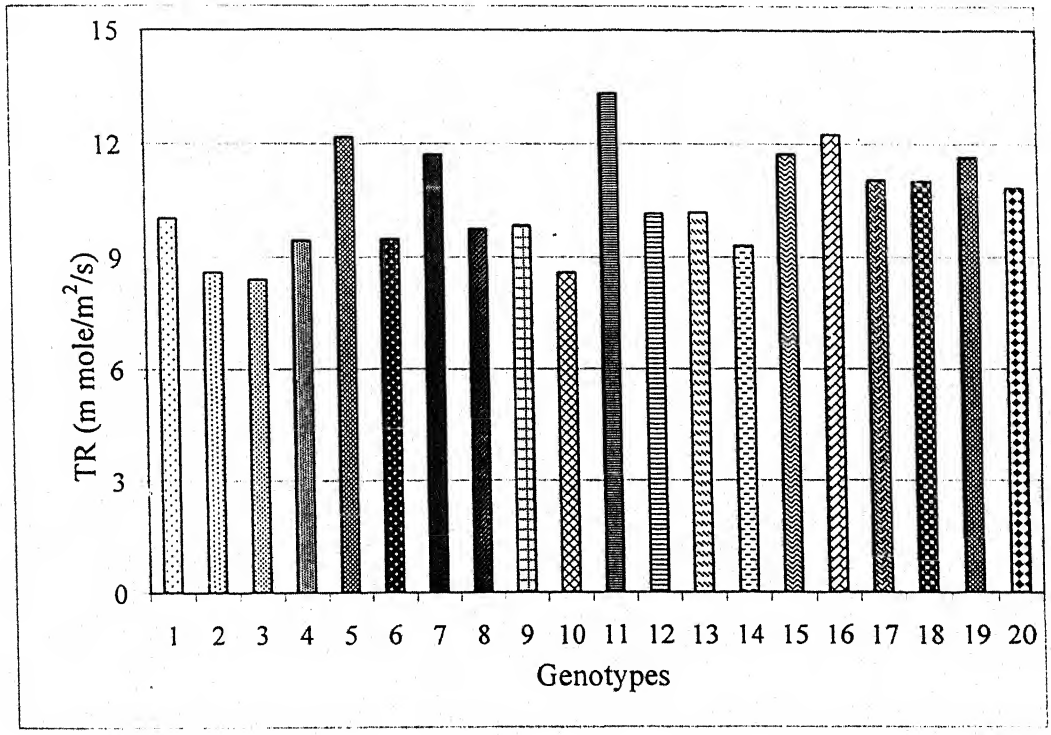


Figure 10. Rate of transpiration in different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

Table 8. Rate of photosynthesis and transpiration in different genotypes of *Stylosanthes.*

| Genotypes | PN (μ mole/$m^2$/s) | | | TR (m mole/$m^2$/s) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 20.54 | 25.63 | 23.08 | 8.48 | 11.59 | 10.03 |
| *S. hamata* 110135 | 17.39 | 21.92 | 19.65 | 7.84 | 9.34 | 8.59 |
| *S. hamata* 61670 | 20.94 | 23.50 | 22.22 | 7.59 | 9.22 | 8.40 |
| *S. scabra* 36260 | 20.86 | 25.72 | 23.29 | 7.63 | 11.25 | 9.44 |
| *S. scabra* 93116 | 18.90 | 23.30 | 21.10 | 10.83 | 13.52 | 12.17 |
| *S. scabra* cv. fitzroy | 21.40 | 22.81 | 22.10 | 7.79 | 11.16 | 9.47 |
| *S. scabra* cv. seca | 26.69 | 28.66 | 27.67 | 10.32 | 13.10 | 11.71 |
| *S. scabra* q 10042 | 18.93 | 23.50 | 21.21 | 7.87 | 11.62 | 9.74 |
| *S. scabra*RRR 94-100 | 21.70 | 26.35 | 24.02 | 7.92 | 11.74 | 9.83 |
| *S. scabra* RRR 94-86 | 19.84 | 23.23 | 21.53 | 7.54 | 9.62 | 8.58 |
| *S. scabra* RRR 94-93 | 25.71 | 26.53 | 26.12 | 11.54 | 15.12 | 13.33 |
| *S. scabra* RRR 94-97 | 21.42 | 26.11 | 23.76 | 9.13 | 11.17 | 10.15 |
| *S. scabra* RRR 94-96 | 20.27 | 23.61 | 21.94 | 8.77 | 11.59 | 10.18 |
| *S. seabrana* 104710 | 22.21 | 25.80 | 24.00 | 8.69 | 9.89 | 9.29 |
| *S. seabrana* 105546 B | 20.11 | 24.29 | 22.20 | 10.10 | 13.36 | 11.73 |
| *S. seabrana* 110372 | 22.01 | 26.73 | 24.37 | 10.45 | 14.04 | 12.24 |
| *S. seabrana* 2523 | 19.22 | 24.64 | 21.93 | 9.53 | 12.56 | 11.04 |
| *S. seabrana* 2534 | 22.88 | 28.01 | 25.44 | 9.69 | 12.33 | 11.01 |
| *S. seabrana* 2539 | 20.82 | 26.29 | 23.55 | 10.22 | 13.06 | 11.64 |
| *S. viscosa* | 21.07 | 23.38 | 22.22 | 9.16 | 12.51 | 10.83 |
| CD at 5% | 2.905 | 3.820 | - | N.S. | 1.704 | - |

## 5. Stomatal Conductance

The behavior of all the genotypes with respect to stomatal conductance (CS) is given in table 9 and figure 11. On average of two years data the stomatal conductance ranged from 0.58 ($cm^2$/sec) to 1.12 ($cm^2$/sec) being maximum in *S. seabrana* 2534 followed by *S. scabra* cv. seca and minimum in *S. hamata* 110135 and *S. scabra* cv q 10042 which was at par to *S. hamata* diploid (61670). Almost similar trend was observed during both the years of crop growth. However, the stomatal conductance during the second year of crop growth was higher as compared to the first year growth.

Table 9. Variation in stomatal conductance in different genotypes of *Stylosanthes.*

| Genotypes | Stomatal conductance (cm2/s) | | |
|---|---|---|---|
| | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 0.71 | 1.19 | 0.95 |
| *S. hamata* 110135 | 0.41 | 0.75 | 0.58 |
| *S. hamata* 61670 | 0.43 | 0.76 | 0.59 |
| *S. scabra* 36260 | 0.47 | 0.96 | 0.71 |
| *S. scabra* 93116 | 0.78 | 1.30 | 1.04 |
| *S. scabra* cv. fitzroy | 0.49 | 0.80 | 0.64 |
| *S. scabra* cv. seca | 0.91 | 1.30 | 1.10 |
| *S. scabra* q 10042 | 0.37 | 0.80 | 0.58 |
| *S. scabra*RRR 94-100 | 0.50 | 1.01 | 0.75 |
| *S. scabra* RRR 94-86 | 0.55 | 0.84 | 0.69 |
| *S. scabra* RRR 94-93 | 0.74 | 0.92 | 0.83 |
| *S. scabra* RRR 94-97 | 0.70 | 1.12 | 0.91 |
| *S. scabra* RRR 94-96 | 0.52 | 0.92 | 0.72 |
| *S. seabrana* 104710 | 0.56 | 0.98 | 0.77 |
| *S. seabrana* 105546 B | 0.65 | 1.38 | 1.01 |
| *S. seabrana* 110372 | 0.66 | 1.18 | 0.92 |

| | | | |
|---|---|---|---|
| *S. seabrana* 2523 | 0.51 | 1.13 | 0.82 |
| *S. seabrana* 2534 | 0.63 | 1.62 | 1.12 |
| *S. seabrana* 2539 | 0.68 | 1.11 | 0.89 |
| *S. viscosa* | 0.60 | 0.99 | 0.79 |
| CD at 5% | NS | 0.390 | - |

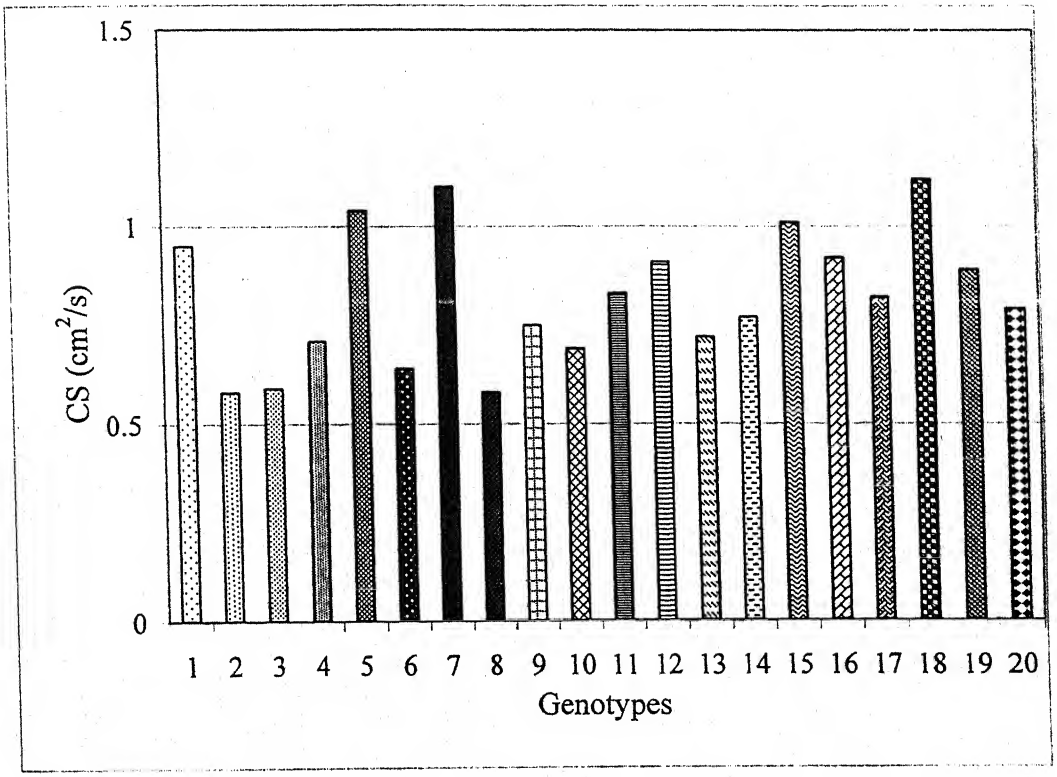


Figure 11. Variation in stomatal conductance in different genotypes of *Stylosanthes*

(Average of Ist and IInd year).

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

Table 10. Variation in leaf temperature (LT) and intercellular $CO_2$ concentration (CINT) in different genotypes of *Stylosanthes.*

| Genotypes | LT ($^0$C ) | | | CINT ( ppm ) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 30.87 | 32.18 | 31.52 | 224.00 | 254.50 | 239.25 |
| *S. hamata* 110135 | 31.67 | 33.06 | 32.36 | 206.30 | 229.90 | 218.10 |
| *S. hamata* 61670 | 31.03 | 33.69 | 32.36 | 225.80 | 226.72 | 226.26 |
| *S. scabra* 36260 | 33.68 | 34.57 | 34.12 | 213.70 | 233.64 | 223.64 |
| *S. scabra* 93116 | 30.98 | 33.34 | 32.16 | 196.90 | 210.42 | 203.66 |
| *S. scabra* cv. fitzroy | 31.66 | 32.75 | 32.20 | 180.50 | 227.30 | 203.90 |
| *S. scabra* cv. seca | 30.51 | 32.72 | 31.61 | 189.70 | 209.32 | 199.51 |
| *S. scabra* q 10042 | 32.35 | 33.48 | 32.91 | 185.30 | 220.93 | 203.11 |
| *S. scabra*RRR 94-100 | 32.58 | 34.39 | 33.48 | 177.7 | 197.53 | 187.61 |
| *S. scabra* RRR 94-86 | 32.39 | 33.44 | 32.91 | 189.8 | 218.79 | 204.29 |
| *S. scabra* RRR 94-93 | 30.00 | 33.30 | 31.65 | 217.90 | 234.06 | 225.98 |
| *S. scabra* RRR 94-97 | 30.11 | 31.88 | 30.99 | 207.70 | 231.22 | 219.46 |
| *S. scabra* RRR 94-96 | 31.19 | 31.84 | 31.51 | 203.90 | 248.75 | 226.32 |
| *S. seabrana* 104710 | 32.28 | 33.99 | 33.13 | 185.20 | 204.65 | 194.92 |
| *S. seabrana* 105546 B | 32.39 | 33.39 | 32.89 | 219.70 | 246.31 | 233.00 |
| *S. seabrana* 110372 | 32.15 | 33.83 | 32.99 | 213.70 | 224.61 | 219.15 |
| *S. seabrana* 2523 | 32.57 | 33.26 | 32.91 | 207.20 | 213.61 | 210.40 |
| *S. seabrana* 2534 | 32.63 | 34.41 | 33.52 | 183.10 | 203.25 | 193.17 |
| *S. seabrana* 2539 | 32.62 | 34.37 | 33.49 | 224.60 | 238.40 | 231.50 |
| *S. viscosa* | 32.44 | 34.23 | 33.33 | 198.00 | 225.05 | 211.52 |
| CD at 5% | 0.0506 | 0.401 | - | 31.049 | 17.939 | - |

## 5. Intercellular $CO_2$ concentration

The intercellular $CO_2$ concentration in all the genotypes in shown in table 10. As apparent from the mean values the higher intercellular $CO_2$ concentration was recorded in *S. hamata* 110123 (239.25 ppm) followed by *S. seabrana* 105546 B (233.00 ppm) and lowest in *S. scabra* RRR 94-100 (187.61 ppm). Although no definite trend was observed in intercellular $CO_2$ concentration during both the years of growth but the intercellular $CO_2$ concentration was observed slightly higher in the second year.

## 6. Carboxylation efficiency (PN/CINT)

Carboxylation efficiency, which is calculated as the ratio of PN/CINT in all the genotypes is given in table 11. The maximum carboxylation efficiency was recorded in *S. scabra* cv seca followed by *S. scabra* RRR 94-100 and *S. seabrana* 2534 and minimum in *S. hamata* 100135. However, the corboxylation efficiency was at par in all the genotypes of *S. seabrana* and *S. scabra.*

## 7. Water use efficiency (PN/TR)

The ratio between photosynthesis and transpiration which indicate water use efficiency was found to be highest in *S. scabra* (RRR 94-100) and minimum in *S. scabra* (93116) (Table 11). Similar trend was observed during the first year of crop growth while in the second year the trend was different. Overall the water use efficiency was calculated to be higher in all the genotypes in the first year as compared to the second year of the crop growth. Most of the genotypes were at par in their water use efficiency.

Table. 11 Carboxylation efficiency (PN/CINT) and water use efficiency (PN/TR) in different genotypes of *Stylosanthes*

| Genotypes | PN/CINT | | | PN/TR | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 0.09 | 0.10 | 0.09 | 2.42 | 2.21 | 2.31 |
| *S. hamata* 110135 | 0.08 | 0.09 | 0.08 | 2.97 | 2.34 | 2.65 |
| *S. hamata* 61670 | 0.09 | 0.10 | 0.09 | 3.74 | 2.54 | 3.14 |
| *S. scabra* 36260 | 0.09 | 0.11 | 0.10 | 2.73 | 2.28 | 2.50 |
| *S. scabra* 93116 | 0.09 | 0.11 | 0.10 | 1.74 | 1.72 | 1.73 |
| *S. scabra* cv. fitzroy | 0.11 | 0.10 | 0.10 | 2.74 | 2.04 | 2.39 |
| *S. scabra* cv. seca | 0.14 | 0.13 | 0.13 | 2.58 | 2.18 | 2.38 |
| *S. scabra* q 10042 | 0.10 | 0.10 | 0.10 | 2.40 | 2.02 | 2.21 |
| *S. scabra*RRR 94-100 | 0.12 | 0.13 | 0.12 | 4.41 | 2.24 | 3.32 |
| *S. scabra* RRR 94-86 | 0.10 | 0.10 | 0.10 | 3.58 | 2.41 | 2.99 |
| *S. scabra* RRR 94-93 | 0.11 | 0.10 | 0.10 | 2.22 | 1.75 | 1.98 |
| *S. scabra* RRR 94-97 | 0.10 | 0.11 | 0.10 | 2.34 | 2.22 | 2.28 |
| *S. scabra* RRR 94-96 | 0.09 | 0.09 | 0.09 | 2.31 | 2.03 | 2.17 |
| *S. seabrana* 104710 | 0.11 | 0.12 | 0.11 | 2.55 | 2.60 | 2.30 |
| *S. seabrana* 105546 B | 0.09 | 0.09 | 0.09 | 1.99 | 1.81 | 1.90 |
| *S. seabrana* 110372 | 0.10 | 0.11 | 0.10 | 2.10 | 1.90 | 2.00 |
| *S. seabrana* 2523 | 0.09 | 0.11 | 0.10 | 2.01 | 1.96 | 1.98 |
| *S. seabrana* 2534 | 0.12 | 0.13 | 0.12 | 2.36 | 2.27 | 2.31 |
| *S. seabrana* 2539 | 0.09 | 0.11 | 0.10 | 2.03 | 2.01 | 2.02 |
| *S. viscosa* | 0.10 | 0.10 | 0.10 | 2.30 | 1.86 | 2.08 |
| CD at 5% | 0.007 | 0.015 | - | 0.436 | NS | - |

### 4.1.4 Biochemical characters

#### (i) Photosynthetic pigment

Genotypic variation in accumulation of chlorophyll (Chl a, Chl b, Chl a+b and chl a/b) were estimated in different genotypes of *Stylosanthes* and data presented in table 12 and 13. In general all the genotypes accumulated higher chlorophyll a as compared to chl b. The variability in the chlorophyll accumulation was observed during both the years. The accumulation of chlorophyll a ranged from 0.58 mg/gm fresh weight (*S. scabra* RRR 94-97) to 1.30 mg/gm (*S. seabrana* 104710) whereas chlorophyll b ranged from 0.19 mg/gm (*S. scabra* RRR 94-96) to 0.38 mg/gm fresh weight (*S. scabrena* 104710). Similarly the total chlorophyll (chl a +b) was estimated to be highest in *S. seabrana* 104710 and lowest in *S. seabrana* 110372. The chlorophyll a: b ratio of genotypes was calculated to be higher in *S. hamata* and lowest in *S. scabra* RRR 94-93. The chlorophyll a:b was higher in the genotypes of *S. hamata* which may be due to the lower accumulation of chlorophyll b. The data were significant at P 0.05.

Table 12. Photosynthetic pigment (chl a and chl b) in different genotypes of *Stylosanthes.*

| Genotypes | Chl a (mg $g^{-1}$ fresh wt) | | | Chl b (mg $g^{-1}$ fresh wt) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 0.93 | 0.85 | 0.89 | 0.26 | 0.21 | 0.23 |
| *S. hamata* 110135 | 1.05 | 0.96 | 1.00 | 0.34 | 0.27 | 0.30 |
| *S. hamata* 61670 | 0.98 | 0.92 | 0.95 | 0.33 | 0.26 | 0.29 |
| *S. scabra* 36260 | 1.13 | 0.98 | 1.05 | 0.48 | 0.31 | 0.39 |
| *S. scabra* 93116 | 0.70 | 0.66 | 0.68 | 0.23 | 0.26 | 0.24 |
| *S. scabra* cv. Fitzroy | 0.90 | 0.76 | 0.83 | 0.30 | 0.24 | 0.27 |
| *S. scabra* cv. Seca | 0.85 | 0.72 | 0.78 | 0.29 | 0.22 | 0.25 |
| *S. scabra* q 10042 | 0.99 | 0.86 | 0.92 | 0.34 | 0.28 | 0.31 |
| *S. scabra*RRR 94-100 | 1.03 | 0.91 | 0.97 | 0.36 | 0.32 | 0.34 |
| *S. scabra* RRR 94-86 | 1.06 | 0.96 | 1.01 | 0.40 | 0.34 | 0.37 |
| *S. scabra* RRR 94-93 | 1.01 | 0.88 | 0.94 | 0.41 | 0.39 | 0.40 |
| *S. scabra* RRR 94-97 | 0.50 | 0.66 | 0.58 | 0.20 | 0.22 | 0.21 |
| *S. scabra* RRR 94-96 | 0.59 | 0.61 | 0.60 | 0.21 | 0.18 | 0.19 |
| *S. seabrana* 104710 | 1.29 | 1.31 | 1.30 | 0.41 | 0.36 | 0.38 |
| *S. seabrana* 105546 B | 0.88 | 0.92 | 0.90 | 0.25 | 0.26 | 0.25 |
| *S. seabrana* 110372 | 0.63 | 0.56 | 0.59 | 0.20 | 0.22 | 0.21 |
| *S. seabrana* 2523 | 1.09 | 0.86 | 0.97 | 0.36 | 0.27 | 0.31 |
| *S. seabrana* 2534 | 0.80 | 0.82 | 0.81 | 0.30 | 0.26 | 0.28 |
| *S. seabrana* 2539 | 1.07 | 0.90 | 0.98 | 0.38 | 0.29 | 0.33 |
| *S. viscose* | 0.78 | 0.64 | 0.71 | 0.30 | 0.25 | 0.27 |
| CD at 5% | 0.052 | 0.036 | - | 0.008 | 0.005 | - |

Table 13. Total chlorophyl (chl a + b) and chlorophyll a, b, ratio (chl a : b ) in different genotypes of *Stylosanthes*.

| Genotypes | Chl a+b (mg $g^{-1}$ fresh wt) | | | Chl a:b | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 1.19 | 1.06 | 1.12 | 3.37 | 4.04 | 3.86 |
| *S. hamata* 110135 | 1.39 | 1.23 | 1.46 | 3.08 | 3.55 | 3.31 |
| *S. hamata* 61670 | 1.31 | 1.18 | 1.24 | 2.96 | 3.53 | 3.24 |
| *S. scabra* 36260 | 1.61 | 1.29 | 1.45 | 2.35 | 3.16 | 2.75 |
| *S. scabra* 93116 | 0.93 | 0.92 | 0.92 | 3.04 | 2.53 | 2.78 |
| *S. scabra* cv. Fitzroy | 1.20 | 1.00 | 1.10 | 3.00 | 3.16 | 3.08 |
| *S. scabra* cv. Seca | 1.14 | 0.94 | 1.04 | 2.93 | 3.27 | 3.10 |
| *S. scabra* q 10042 | 1.33 | 1.14 | 1.23 | 2.91 | 3.07 | 2.99 |
| *S. scabra*RRR 94-100 | 1.39 | 1.23 | 1.31 | 2.86 | 2.84 | 2.85 |
| *S. scabra* RRR 94-86 | 1.56 | 1.30 | 1.43 | 2.90 | 2.82 | 2.86 |
| *S. scabra* RRR 94-93 | 1.42 | 1.27 | 1.34 | 2.46 | 2.25 | 2.35 |
| *S. scabra* RRR 94-97 | 0.70 | 0.88 | 0.79 | 2.50 | 3.00 | 2.75 |
| *S. scabra* RRR 94-96 | 0.80 | 0.79 | 0.79 | 2.80 | 3.66 | 3.23 |
| *S. seabrana* 104710 | 1.70 | 1.67 | 1.68 | 3.14 | 3.63 | 3.38 |
| *S. seabrana* 105546 B | 1.13 | 1.18 | 1.15 | 3.52 | 3.53 | 3.52 |
| *S. seabrana* 110372 | 0.63 | 0.78 | 0.70 | 2.15 | 2.54 | 2.34 |
| *S. seabrana* 2523 | 1.45 | 1.13 | 1.29 | 3.02 | 3.18 | 3.10 |
| *S. seabrana* 2534 | 1.10 | 1.08 | 1.09 | 2.66 | 3.15 | 2.90 |
| *S. seabrana* 2539 | 1.45 | 1.19 | 1.32 | 2.81 | 3.10 | 2.95 |
| *S. viscose* | 1.08 | 0.89 | 0.98 | 2.60 | 2.56 | 2.58 |
| CD at 5% | 0.054 | 0.048 | - | 2.429 | 0.255 | - |

### (ii) Nitrate reductase activity

Nitrate reductase activity was estimated in the fresh leaves of different genotypes at 50% flowering stage and data are presented in table 14. On average of the data of two years the NR activity ranged from 218.37 to 600.28 (µ mole nitrite / g fresh wt / h). Maximum NR activity was estimated in *S. viscosa* followed by *S. hamata* and *S. seabrana* and minimum NR activity was observed in the genotypes of *S. scabra*. The data presented in the table reveled that large variability exists among the species while among the genotypes with in the same species the variability is very low.

### (iii) Sugar content

Genotypic variation in the accumulation of water soluble sugar in leaves in different genotypes of *Stylosanthes* in given in table 15. The accumulation of sugar content in leaves ranged from 10.71 mg $g^{-1}$ dry wt to 33.93 mg $g^{-1}$ dry wt (Figure 12). On average of both the years higher accumulation of water soluble sugar in leaves was estimated in *S. scabra* cv. seca (33.93 mg $g^{-1}$ dry wt) followed by *S. seabrana* 104710 (31.33 mg $g^{-1}$ dry wt) and minimum in *S. hamata* (diploid) 61670 (10.71 mg $g^{-1}$ dry wt). Similar trend was observed during both the years of experimentation. The data were found statistically significant.

Table 14. Nitrate reductase activity (N R activity) in leaves of different genotypes of *Stylosanthes.*

| Genotypes | N R Activity (µ mole nitrite / g fresh wt / h) | | |
|---|---|---|---|
| | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 385.40 | 365.50 | 375.45 |
| *S. hamata* 110135 | 378.20 | 368.60 | 373.40 |
| *S. hamata* 61670 | 376.50 | 374.42 | 375.46 |
| *S. scabra* 36260 | 223.78 | 232.22 | 228.00 |
| *S. scabra* 93116 | 212.56 | 226.52 | 219.54 |
| *S. scabra* cv. Fitzroy | 232.30 | 228.60 | 230.45 |
| *S. scabra* cv. seca | 226.56 | 224.88 | 225.72 |
| *S. scabra* q 10042 | 232.60 | 242.62 | 237.61 |
| *S. scabra*RRR 94-100 | 228.32 | 232.56 | 230.44 |
| *S. scabra* RRR 94-86 | 226.52 | 229.91 | 228.21 |
| *S. scabra* RRR 94-93 | 214.40 | 222.35 | 218.37 |
| *S. scabra* RRR 94-97 | 220.55 | 226.66 | 223.60 |
| *S. scabra* RRR 94-96 | 226.66 | 231.86 | 229.26 |
| *S. seabrana* 104710 | 238.70 | 240.32 | 239.51 |
| *S. seabrana* 105546 B | 244.30 | 256.44 | 250.37 |
| *S. seabrana* 110372 | 241.90 | 248.20 | 245.05 |
| *S. seabrana* 2523 | 246.42 | 251.12 | 248.77 |
| *S. seabrana* 2534 | 268.58 | 266.60 | 267.59 |
| *S. seabrana* 2539 | 255.55 | 261.72 | 258.63 |
| *S. viscosa* | 643.65 | 556.92 | 600.28 |
| CD at 5% | 4.570 | 5.110 | - |

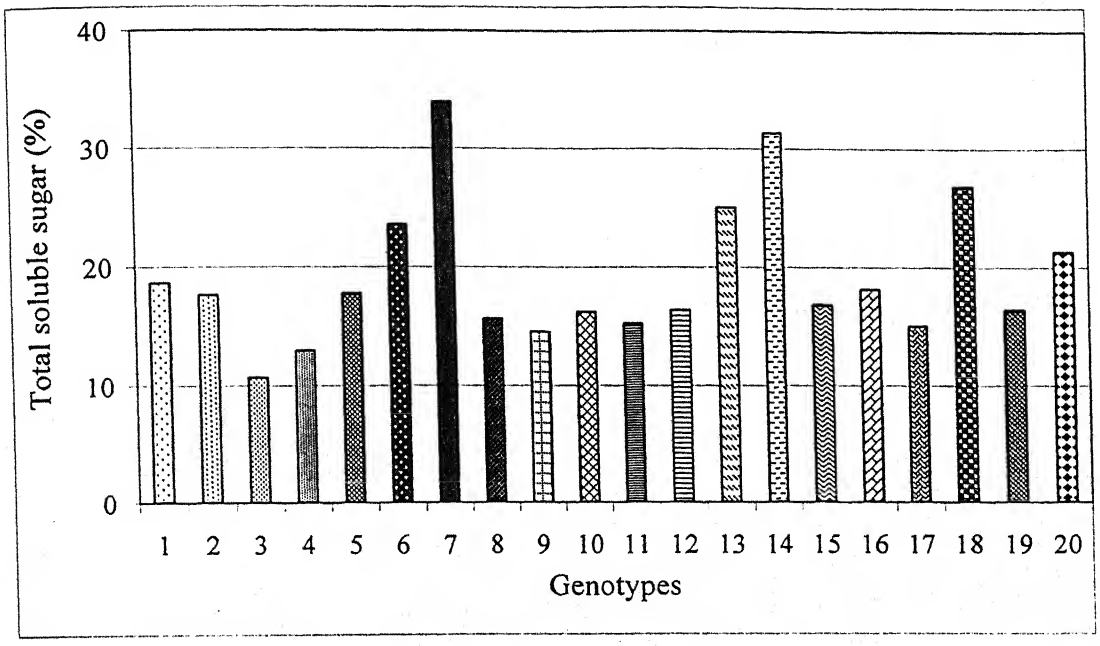


Figure 12. Sugar accumulation in leaves of different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *f*itzroy, 7. *S. scabra* cv. *s*eca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

### (iv) Crude Protein Content

The crude protein content were estimated in different genotypes at 50% flowering stage and data are presented in table 15 and figure 13. The variation in crude protein content in different genotype ranged from 13.91 % to 18.26 %. The crude protein accumulation in all the genotypes of *S. hamata* was higher followed by *S. viscosa* where as the genotypes of *S. scabra* and *S. seabrana* were at par. However, the maximum crude protein content was estimated in *S. scabra* cv. fitzroy (16.27 %) and *S. scabra* q 10042 (16.09 %) among the genotypes of *S. scabra* and *S. seabrana* 2534 (16.44 %) and *S. seabrana* 105546 B (16.11 %) among the genotypes of *S. seabrana*.

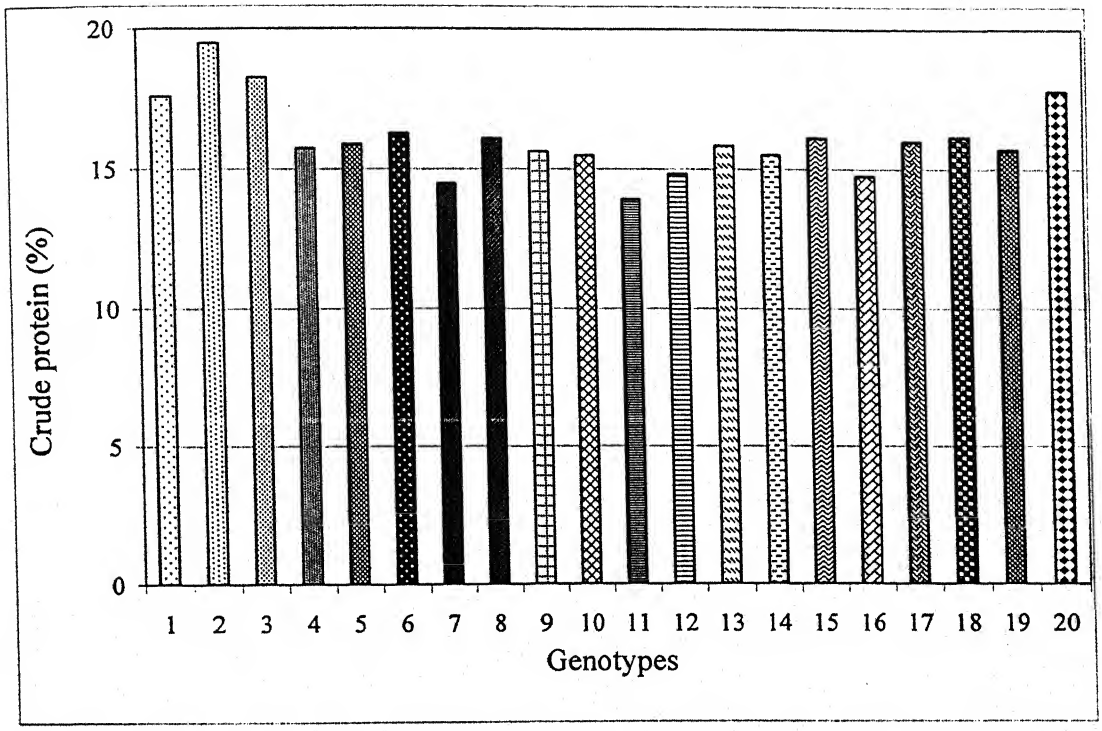


Figure 13. Crude protein on dry weight basis (%) in leaves of different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

Table 15. Sugar accumulation and crude protein in leaves of different genotypes of *Stylosanthes.*

| Genotypes | Total soluble sugar (mg $g^{-1}$ dry wt) | | | Crude protein (%) on dry value | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 17.62 | 19.66 | 18.64 | 18.51 | 16.66 | 17.58 |
| *S. hamata* 110135 | 17.02 | 18.26 | 17.64 | 20.10 | 16.86 | 19.48 |
| *S. hamata* 61670 | 9.07 | 12.36 | 10.71 | 18.97 | 17.56 | 18.26 |
| *S. scabra* 36260 | 12.79 | 13.13 | 12.96 | 15.93 | 15.56 | 15.74 |
| *S. scabra* 93116 | 16.94 | 18.56 | 17.75 | 16.11 | 15.66 | 15.88 |
| *S. scabra* cv. fitzroy | 23.28 | 23.86 | 23.57 | 16.68 | 15.86 | 16.27 |
| *S. scabra* cv. seca | 34.20 | 33.66 | 33.93 | 15.01 | 13.96 | 14.48 |
| *S. scabra* q 10042 | 14.81 | 16.52 | 15.66 | 16.95 | 15.23 | 16.09 |
| *S. scabra*RRR 94-100 | 13.99 | 15.12 | 14.55 | 16.23 | 15.02 | 15.62 |
| *S. scabra* RRR 94-86 | 15.91 | 16.62 | 16.26 | 15.85 | 15.12 | 15.48 |
| *S. scabra* RRR 94-93 | 14.77 | 15.76 | 15.26 | 14.86 | 12.96 | 13.91 |
| *S. scabra* RRR 94-97 | 15.92 | 16.86 | 16.39 | 15.11 | 14.56 | 14.83 |
| *S. scabra* RRR 94-96 | 24.80 | 25.24 | 25.02 | 16.50 | 15.16 | 15.83 |
| *S. seabrana* 104710 | 30.81 | 31.86 | 31.33 | 15.79 | 15.23 | 15.51 |
| *S. seabrana* 105546 B | 15.68 | 17.78 | 16.82 | 16.78 | 15.44 | 16.11 |
| *S. seabrana* 110372 | 17.83 | 18.43 | 18.13 | 14.93 | 14.56 | 14.74 |
| *S. seabrana* 2523 | 14.43 | 15.63 | 15.03 | 16.11 | 15.86 | 15.98 |
| *S. seabrana* 2534 | 25.93 | 27.72 | 26.82 | 16.47 | 15.82 | 16.14 |
| *S. seabrana* 2539 | 14.94 | 17.86 | 16.40 | 16.29 | 15.12 | 15.70 |
| *S. viscosa* | 20.34 | 22.23 | 21.28 | 18.34 | 17.24 | 17.79 |
| CD at 5% | 0.483 | 0.512 | - | 0.143 | 0.123 | - |

## 4.1.5. Flowering and Seed Yield

### (i) Flowering behavior

All the twenty genotypes of *Stylosanthes* were observed for flowering behavior. In all the genotypes the flowering started (table 16,17 and figure 14) in the first and second week of September in the first year whereas during the second year the flowering initiation was observed in second week of August in some genotypes and first week of September in other genotypesDuring second year. All the genotypes attended 50% flowering in the month of October and November and completed in November, December and January according to flowering initiation. As evident from the table 16 and 17 there is variability in the flowering. In different genotypes (figure 14) the flowering duration ranged from 58 days to 120 days in the first year. In second year in general the genotypes of *S. hamata* (110123 and 110135) and *S. seabrana* were early flowering where as most of the genotypes of *S. scabra* were late flowering. In general the flowering period of all the genotypes was from 67 to 130 days.

Table 16. Genotypic variability in flowering behavior in *Stylosanthes* genotypes during the first year.

| Genotypes | Flowering initiation | 50 % flowering | Flowering completion | Span of flowering |
|---|---|---|---|---|
| *S. hamata* 110123 | 04.09.02 | 20.10.02 | 10.11.02 | 66 |
| *S. hamata* 110135 | 04.09.02 | 24.10.02 | 10.11.02 | 68 |
| *S. hamata* 61670 | 02.09.02 | 02.11.02 | 20.12.02 | 113 |
| *S. scabra* 36260 | 12.09.02 | 22.10.02 | 30.11.02 | 74 |
| *S. scabra* 93116 | 04.09.02 | 15.11.02 | 02.01.03 | 120 |
| *S. scabra* cv. fitzroy | 04.09.02 | 25.11.02 | 02.01.03 | 120 |
| *S. scabra* cv. seca | 06.09.02 | 10.11.02 | 03.01.03 | 119 |
| *S. scabra* q 10042 | 04.09.02 | 24.11.02 | 02.01.03 | 120 |
| *S. scabra*RRR 94-100 | 04.09.02 | 07.11.02 | 02.01.03 | 117 |
| *S. scabra* RRR 94-86 | 04.09.02 | 20.10.02 | 10.11.02 | 68 |
| *S. scabra* RRR 94-93 | 04.09.02 | 15.11.02 | 02.01.03 | 120 |
| *S. scabra* RRR 94-97 | 04.09.02 | 20.11.02 | 02.01.03 | 120 |
| *S. scabra* RRR 94-96 | 04.09.02 | 15.11.02 | 02.01.03 | 120 |
| *S. seabrana* 104710 | 01.09.02 | 02.10.02 | 24.10.02 | 58 |
| *S. seabrana* 105546 B | 04.09.02 | 15.10.02 | 09.11.02 | 66 |
| *S. seabrana* 110372 | 04.09.02 | 20.10.02 | 15.11.02 | 72 |
| *S. seabrana* 2523 | 01.09.02 | 08.10.02 | 02.11.02 | 62 |
| *S. seabrana* 2534 | 01.09.02 | 02.10.02 | 12.11.02 | 74 |
| *S. seabrana* 2539 | 01.09.02 | 02.10.02 | 05.11.02 | 66 |
| *S. viscosa* | 08.09.02 | 20.10.02 | 20.11.02 | 70 |

Table 17. Genotypic variability in flowering behavior in *Stylosanthes* genotypes during second year.

| Genotypes | Flowering initiation | 50 % flowering | Flowering completion | Span of flowering |
|---|---|---|---|---|
| *S. hamata* 110123 | 10.08.03 | 03.11.03 | 05.11.03 | 98 |
| *S. hamata* 110135 | 10.08.03 | 30.10.03 | 03.11.03 | 86 |
| *S. hamata* 61670 | 10.08.03 | 03.11.03 | 18.12.03 | 131 |
| *S. scabra* 36260 | 26.08.03 | 22.10.03 | 10.11.03 | 77 |
| *S. scabra* 93116 | 12.08.03 | 03.11.03 | 30.12.03 | 141 |
| *S. scabra* cv. fitzroy | 08.09.03 | 11.11.03 | 27.12.03 | 111 |
| *S. scabra* cv. seca | 19.08.03 | 11.11.03 | 30.12.03 | 86 |
| *S. scabra* q 10042 | 22.08.03 | 03.11.03 | 30.12.03 | 131 |
| *S. scabra*RRR 94-100 | 19.08.03 | 11.11.03 | 25.12.03 | 129 |
| *S. scabra* RRR 94-86 | 22.08.03 | 28.10.03 | 15.11.03 | 86 |
| *S. scabra* RRR 94-93 | 19.08.03 | 06.11.03 | 25.12.03 | 129 |
| *S. scabra* RRR 94-97 | 08.09.03 | 11.11.03 | 25.12.03 | 109 |
| *S. scabra* RRR 94-96 | 15.09.03 | 11.11.03 | 27.12.03 | 111 |
| *S. seabrana* 104710 | 10.08.03 | 05.10.03 | 03.11.03 | 86 |
| *S. seabrana* 105546 B | 10.08.03 | 08.10.03 | 03.11.03 | 86 |
| *S. seabrana* 110372 | 10.08.03 | 25.10.03 | 10.11.03 | 93 |
| *S. seabrana* 2523 | 10.08.03 | 08.10.03 | 05.11.03 | 88 |
| *S. seabrana* 2534 | 10.08.03 | 08.10.03 | 05.11.03 | 88 |
| *S. seabrana* 2539 | 10.08.03 | 08.10.03 | 03.11.03 | 86 |
| *S. viscosa* | 19.08.03 | 14.10.03 | 03.11.03 | 77 |

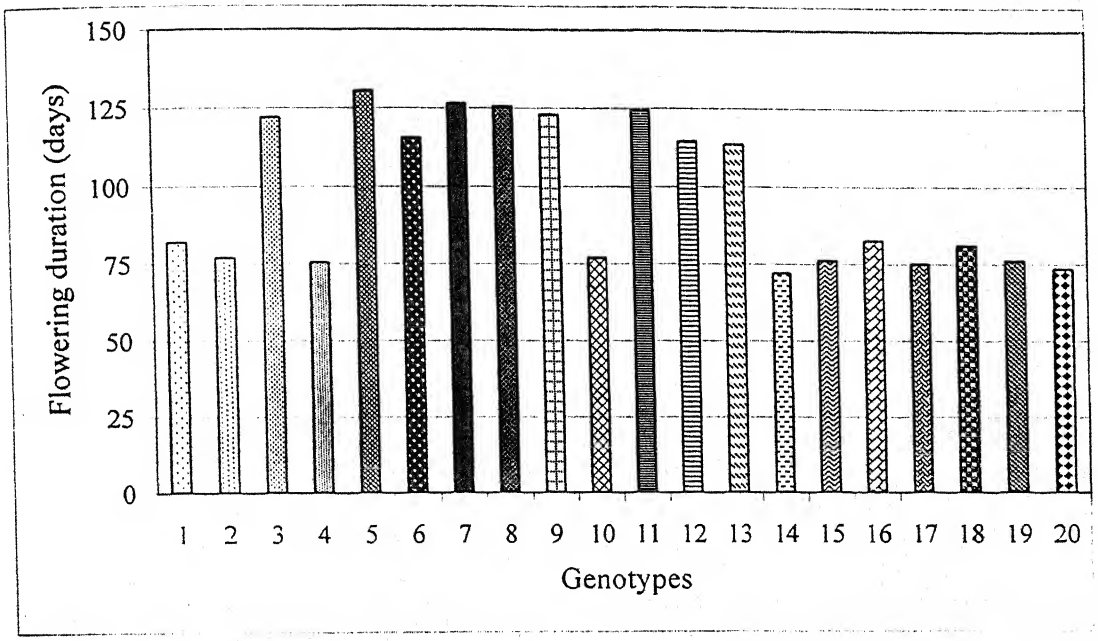


Figure 14. Flowering duration in different genotypes of *Stylosanthes* (Average of first and second years data).

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

**(ii) Seed Yield**

Genotypic variation in seed yield / plant was observed and data are presented in table 18 and figure 15. On average of both the years maximum seed yield was recorded in *S. seabra*na 2534 (27.38 gm/plant) followed by *S. seabrana* 2523 (24.12 gm/plant) and minimum in *S. hamata* diploid 61670 (5.15 gm/plant). The seed production in all the genotypes was lower during the first year as it was the establishment year. During the second year the seed production per plant was much higher and in same genotypes it was 2 to 4 folds higher in case of *S. scabra* and *S. seabrana* genotypes. As apparent from the data the seed yield ranged from 68.88 kg/ha to 229.59 kg/ha in first year and 111.18 kg/ha

to 438.92 kg/ha during the second year. On average the seed yield per hactare ranged from 90.03 kg/ha (*S. hamata* 110123) to 328 kg/ha (*S. seabrana* 2534). As evident from the data the genotypes of *S. seabrana* were high seed yielder followed by the accessions of *S. scabra* where as the genotypes the *S. hamata* were lower seed yielder. The data indicated that their is large variability in the yield characters among the genotypes of *Stylosanthes.* The data were statistically significant at P 0.05 (Table 18).

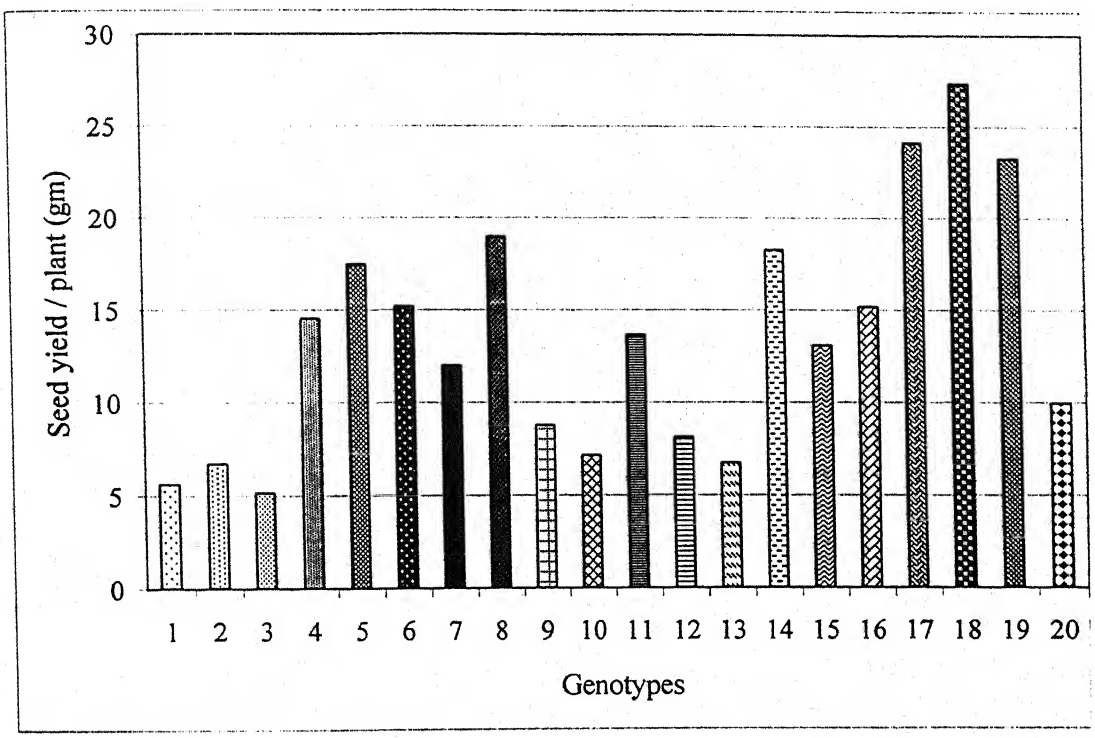


Figure 15. Seed yield (gm) in different genotypes of *Stylosanthes* (Average of first and second years data).

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

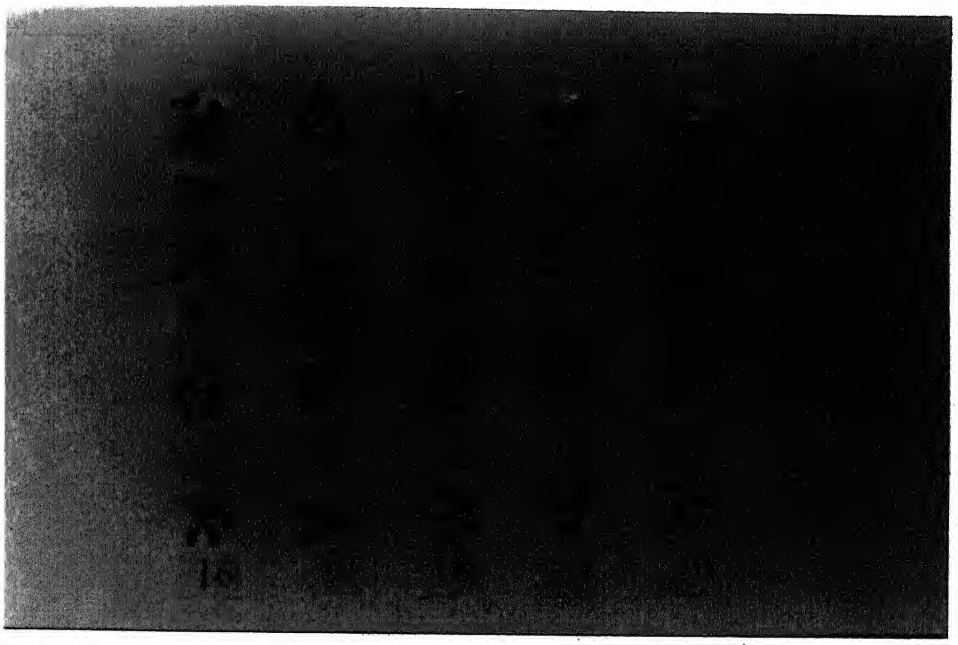

**Plate VI. Variation in seed shape and size in various genotypes of *Stylosanthes.***

Table 18. Seed yield in different genotypes of *Stylosanthes.*

| Genotypes | Seed yield / plant (gm) | | | Seed yield (kg / ha) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 4.31 | 6.94 | 5.62 | 68.88 | 111.18 | 90.03 |
| *S. hamata* 110135 | 6.06 | 7.37 | 6.71 | 97.00 | 178.49 | 137.74 |
| *S. hamata* 61670 | 3.19 | 7.11 | 5.15 | 51.15 | 167.06 | 109.10 |
| *S. scabra* 36260 | 9.04 | 20.03 | 14.53 | 108.55 | 240.32 | 174.43 |
| *S. scabra* 93116 | 12.50 | 22.43 | 17.46 | 125.01 | 224.28 | 174.64 |
| *S. scabra* cv. fitzroy | 6.97 | 23.40 | 15.18 | 69.69 | 233.95 | 151.82 |
| *S. scabra* cv. seca | 6.79 | 17.19 | 11.98 | 81.45 | 206.22 | 143.83 |
| *S. scabra* q 10042 | 6.50 | 31.45 | 18.97 | 78.04 | 377.46 | 227.75 |
| *S. scabra*RRR 94-100 | 4.49 | 13.01 | 8.75 | 53.94 | 155.55 | 104.74 |
| *S. scabra* RRR 94-86 | 3.46 | 10.82 | 7.14 | 41.46 | 129.81 | 85.63 |
| *S. scabra* RRR 94-93 | 6.53 | 20.75 | 13.64 | 65.34 | 207.46 | 134.40 |
| *S. scabra* RRR 94-97 | 5.86 | 10.35 | 8.11 | 70.36 | 122.21 | 96.28 |
| *S. scabra* RRR 94-96 | 5.33 | 8.15 | 6.74 | 69.90 | 97.75 | 80.82 |
| *S. seabrana* 104710 | 13.32 | 23.20 | 18.26 | 159.84 | 278.38 | 219.11 |
| *S. seabrana* 105546 B | 8.74 | 17.41 | 13.07 | 139.82 | 278.51 | 209.16 |
| *S. seabrana* 110372 | 9.74 | 20.60 | 15.17 | 116.86 | 247.25 | 195.55 |
| *S. seabrana* 2523 | 19.13 | 29.08 | 24.12 | 229.59 | 345.45 | 287.52 |
| *S. seabrana* 2534 | 18.18 | 36.58 | 27.38 | 218.19 | 438.92 | 328.55 |
| *S. seabrana* 2539 | 15.92 | 30.62 | 23.27 | 191.06 | 364.60 | 277.83 |
| *S. viscosa* | 4.33 | 15.54 | 9.94 | 51.98 | 186.46 | 119.22 |
| CD at 5% | 1.784 | 1.513 | - | 21.290 | 29.141 | - |

### (iii) Seed Test Weight

Thousand seeds weight, which represent the seed test weight of each genotype, was recorded and data presented in table 19 and figure 16. On average of both the years the seed test weight ranged from 2.69 gm (*S. scabra* 36260) to 3.55 gm (*S. scabra* RRR 94-93). During the first and second year the seed test weight ranged from 2.64 g to 3.80 gm and 2.54 gm to 3.31 gm respectively. No definite trend was observed in the seed test weight among the genotypes of *S. hamata, S. scabra* and *S. seabrana*. However, most of the genotypes were at par in their seed test weight. The data were statistically significant at P 0.05.

Table 19. Seed test weight in different genotypes of *Stylosanthes.*

| Genotypes | 1000 Seed weight (gm) | | |
|---|---|---|---|
| | Ist Year | IInd Year | Mean |
| *S. hamata* 110123 | 2.64 | 2.86 | 2.75 |
| *S. hamata* 110135 | 3.02 | 3.00 | 3.01 |
| *S. hamata* 61670 | 3.48 | 3.24 | 3.36 |
| *S. scabra* 36260 | 2.84 | 2.55 | 2.69 |
| *S. scabra* 93116 | 3.58 | 3.24 | 3.41 |
| *S. scabra* cv. Fitzroy | 3.04 | 2.92 | 2.98 |
| *S. scabra* cv. seca | 3.34 | 3.05 | 3.19 |
| *S. scabra* q 10042 | 3.33 | 3.24 | 3.28 |
| *S. scabra*RRR 94-100 | 2.99 | 3.06 | 3.02 |
| *S. scabra* RRR 94-86 | 3.05 | 3.02 | 3.03 |
| *S. scabra* RRR 94-93 | 3.80 | 3.31 | 3.55 |
| *S. scabra* RRR 94-97 | 3.15 | 3.12 | 3.13 |
| *S. scabra* RRR 94-96 | 2.80 | 2.90 | 2.85 |
| *S. seabrana* 104710 | 2.85 | 2.73 | 2.79 |
| *S. seabrana* 105546 B | 3.44 | 3.16 | 3.30 |

| | | | |
|---|---|---|---|
| *S. seabrana* 110372 | 2.87 | 3.18 | 3.02 |
| *S. seabrana* 2523 | 3.07 | 3.02 | 3.04 |
| *S. seabrana* 2534 | 3.12 | 3.18 | 3.15 |
| *S. seabrana* 2539 | 3.12 | 3.14 | 3.13 |
| *S. viscosa* | 3.16 | 3.17 | 3.16 |
| CD at 5% | 0.070 | 0.048 | - |

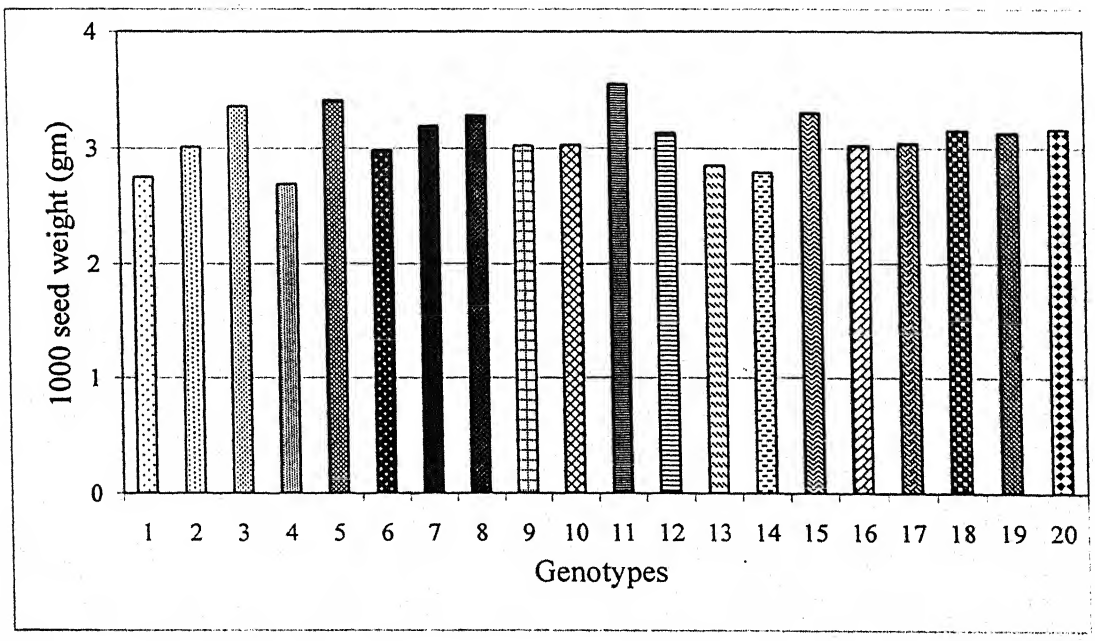


Figure 16. Seed test weight in different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

### 4.1.6 Germination Studies

The seeds of different genotype of *Stylosanthes* were collected during November - December 2003 and stored in polythene begs, (700 gauge) at room temperature. Since the stylo seeds having hard seed coat and required pre showing seed treatment for breaking the seed dormancy to get the better germination. The seeds were tested for seed germination after the eight months of storage in seed germinator at 30 °C and 75% humidity in August 2004. The dormancy breaking seed treatments of $GA_3$ (300 ppm), $KNO_3$ (0.2%), hot water (60 °C), concentrate $H_2SO_4$ (for 5 min) then washing in running tape water for 15 minutes and scarification through coarse sand paper were applied. Following observation were recorded at 21 days of germination.

**(i) Seed germination**

The germination percentage of different genotypes of *Stylosanthes* was recorded and data are presented in table 20 and figure 17, 18, 19, 20, 21, 22 and 23. On average of the germination percentage of different genotypes in various treatments, maximum germination (79%) was recorded in the seeds scarified through sand paper followed by concentrate $H_2SO_4$ treatment (56%) and minimum germination was observed in the control (19%). The effect of $GA_3$ (300 ppm), $KNO_3$ (0.2 %) and hot water (60 °C) treatments were at par with respect to germination. Comparing the genotypic difference of different genotypes of *Stylosanthes*, the maximum germination was recorded in *S. seabrana* (104710) followed by *S. seabrana* 2523, *S. scabra* 93116, *S. hamata* 110123 and *S. seabrana* 105546 B in the scarification treatment and minimum germination was recorded in *S. viscosa*. In control (without giving any seed treatment) maximum seed germination was observed in *S. scabra* (cv. seca) followed by *S. scabra* (RRR 94-100, RRR 94-86), *S. hamata* 110135 and *S. seabrana* 105546 b and minimum in *S. scabra* RRR 94-96, 93116, RRR 94-97 and *S. viscosa*. In some of the genotypes the seed

treatments of $GA_3$ (300 ppm) $KNO_3$ (0.2 %) and hot water (60 °C) has also accelerated seed germination up to 55 % (*S. scabra* cv. seca). The germination of seeds has also improved to double, triple and fourth folds by the treatment of $H_2SO_4$. The result revealed that the germination percentage in different genotype of *Stylosanthes* can be improved by the scarification of seeds.

Table 20. Effect of various seed treatments on seed germination in different genotypes of *Stylosanthes*.

| Genotypes | Germination % | | | | | |
|---|---|---|---|---|---|---|
| | Control | $GA_3$ (300ppm) | $KNO_3$ (0.2%) | Hot water ($60^{0c}$) | $H_2SO_4$ (5 min.) | Scarification |
| *S. hamata* 110123 | 21 | 25 | 25 | 22 | 60 | 88 |
| *S. hamata* 110135 | 28 | 26 | 25 | 35 | 55 | 85 |
| *S. hamata* 61670 | 15 | 25 | 18 | 18 | 70 | 80 |
| *S. scabra* 36260 | 24 | 30 | 30 | 30 | 60 | 58 |
| *S. scabra* 93116 | 10 | 20 | 12 | 22 | 50 | 90 |
| *S. scabra* cv. fitzroy | 20 | 24 | 22 | 20 | 32 | 80 |
| *S. scabra* cv. seca | 32 | 38 | 40 | 55 | 75 | 84 |
| *S. scabra* q 10042 | 20 | 15 | 18 | 20 | 40 | 70 |
| *S. scabra*RRR 94-100 | 30 | 30 | 25 | 20 | 40 | 75 |
| *S. scabra* RRR 94-86 | 28 | 18 | 36 | 35 | 70 | 78 |
| *S. scabra* RRR 94-93 | 16 | 18 | 12 | 20 | 40 | 70 |
| *S. scabra* RRR 94-97 | 10 | 12 | 15 | 15 | 76 | 78 |
| *S. scabra* RRR 94-96 | 10 | 25 | 15 | 18 | 65 | 80 |
| *S. seabrana* 104710 | 20 | 18 | 20 | 22 | 62 | 92 |
| *S. seabrana* 105546 B | 25 | 38 | 32 | 25 | 75 | 88 |
| *S. seabrana* 110372 | 16 | 25 | 18 | 25 | 70 | 80 |

| | | | | | | |
|---|---|---|---|---|---|---|
| *S. seabrana* 2523 | 16 | 20 | 18 | 20 | 66 | 90 |
| *S. seabrana* 2534 | 22 | 18 | 18 | 20 | 38 | 85 |
| *S. seabrana* 2539 | 20 | 15 | 20 | 20 | 35 | 75 |
| *S. viscosa* | 10 | 15 | 36 | 20 | 30 | 55 |
| Average | 19.65 | 22.75 | 22.75 | 24.10 | 55.45 | 79.05 |

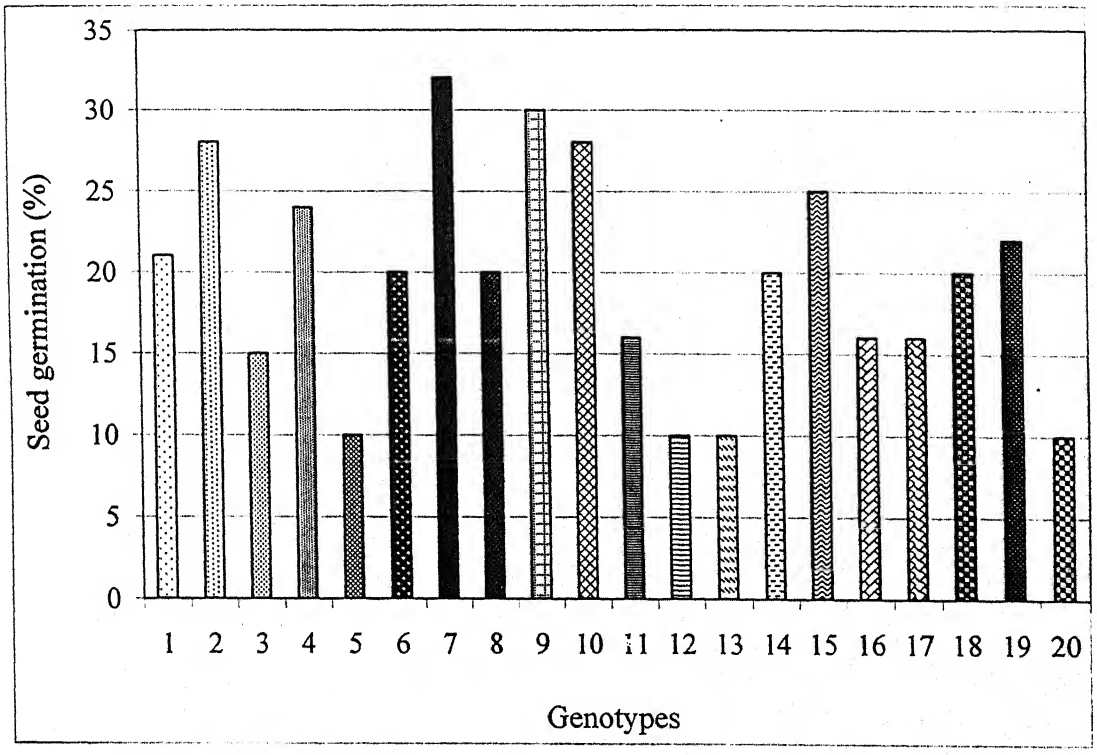


Figure 17. Rate of germination (%) in different genotypes of *Stylosanthes* in control.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

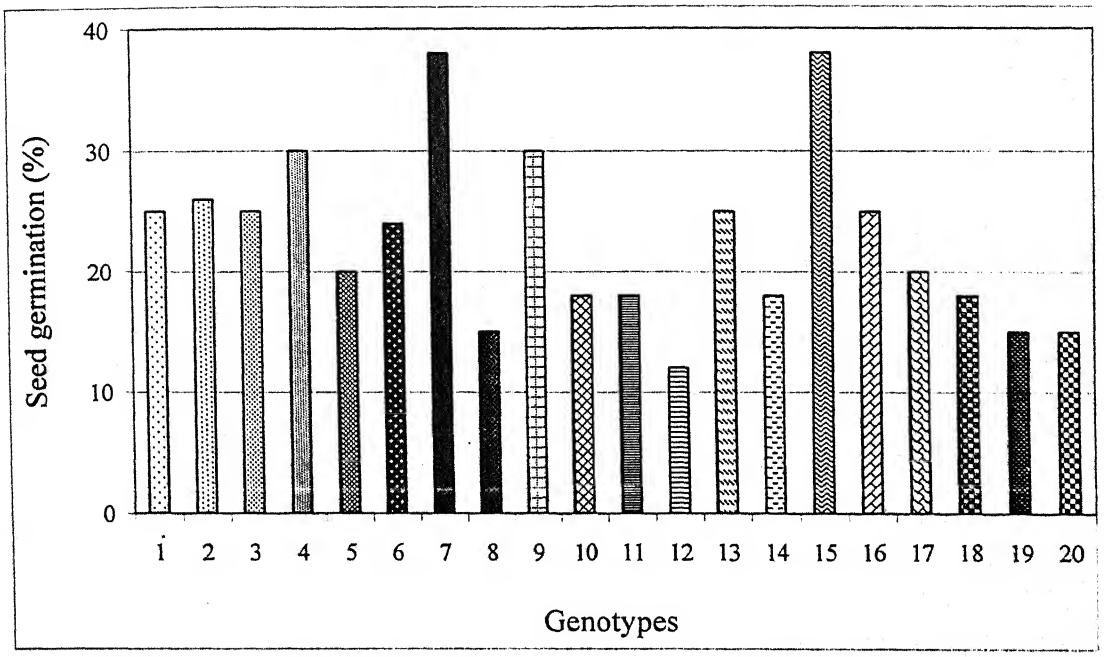


Figure 18. Effect of $GA_3$ (100 ppm) on seed germination (%) in different genotypes of *Stylosanthes.*

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

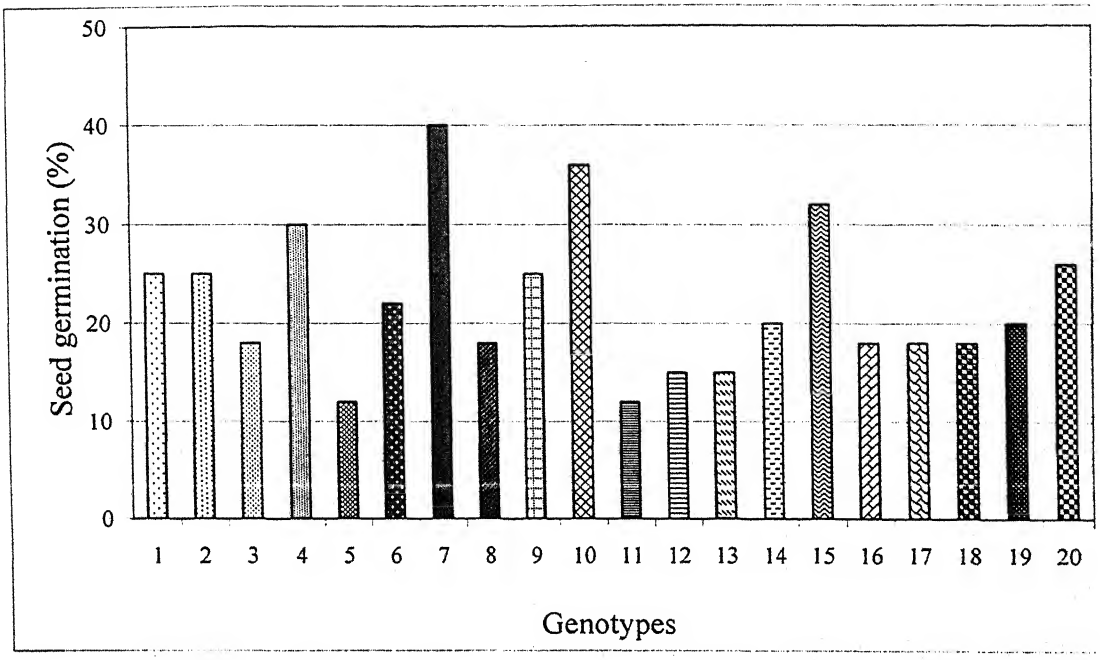


Figure 19. Effect of $KNO_3$ (0.2 %) on seed germination (%) in different genotypes of *Stylosanthes.*

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

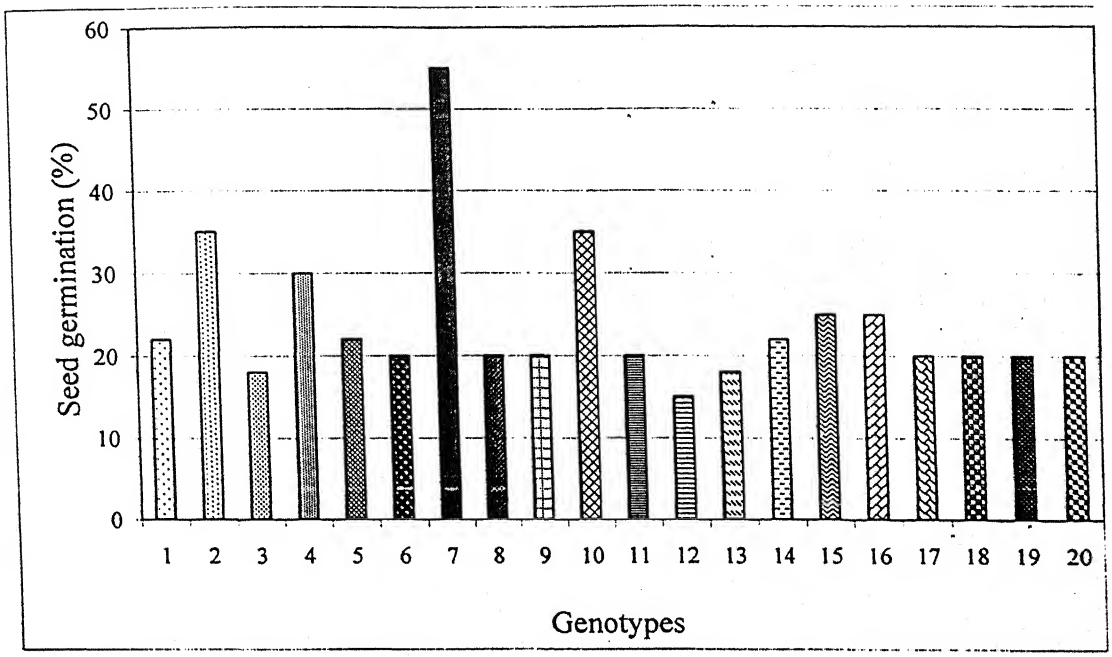


Figure 20. Effect of hot water (60 °C) on seed germination (%) in different genotypes of *Stylosanthes*.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

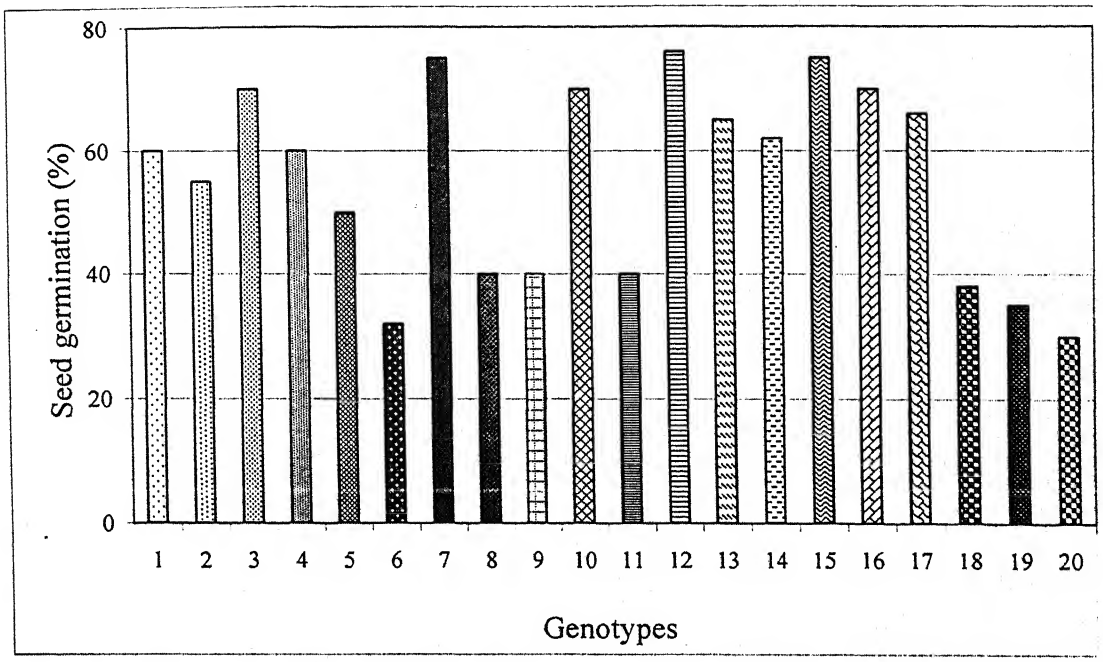


Figure 21. Effect of $H_2SO_4$ (5 min) on seed germination (%) in different genotypes of Stylosanthes.

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. *seca*, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

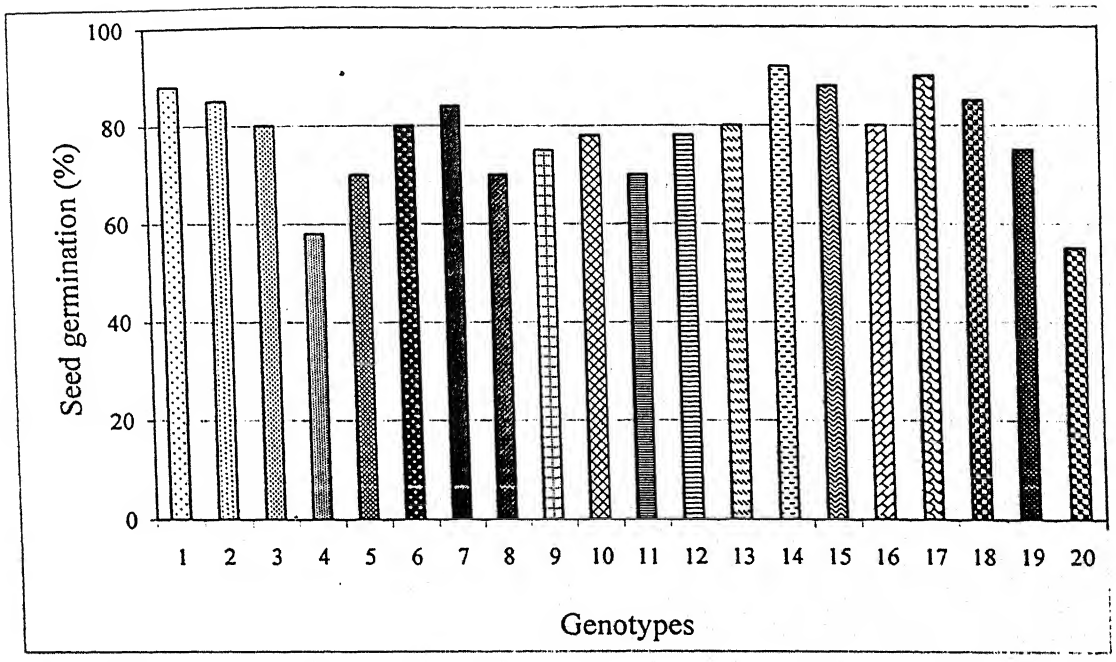


Figure 22. Effect of scarification on seed germination (%) in different genotypes of *Stylosanthes.*

(1. *S. hamata* 110123, 2. *S. hamata* 110135, 3. *S. hamata* 61670, 4. *S. scabra* 36260, 5. *S. scabra* 93116, 6. *S. scabra* cv. *fitzroy*, 7. *S. scabra* cv. seca, 8. *S. scabra* q 10042, 9. *S. scabra*RRR 94-100, 10. *S. scabra* RRR 94-86, 11. *S. scabra* RRR 94-93, 12. *S. scabra* RRR 94-97, 13. *S. scabra* RRR 94-96, 14. *S. seabrana* 104710, 15. *S. seabrana* 105546 B, 16. *S. seabrana* 110372, 17. *S. seabrana* 2523. 18. *S. seabrana* 2534, 19. *S. seabrana* 2539, 20. *S. viscosa*)

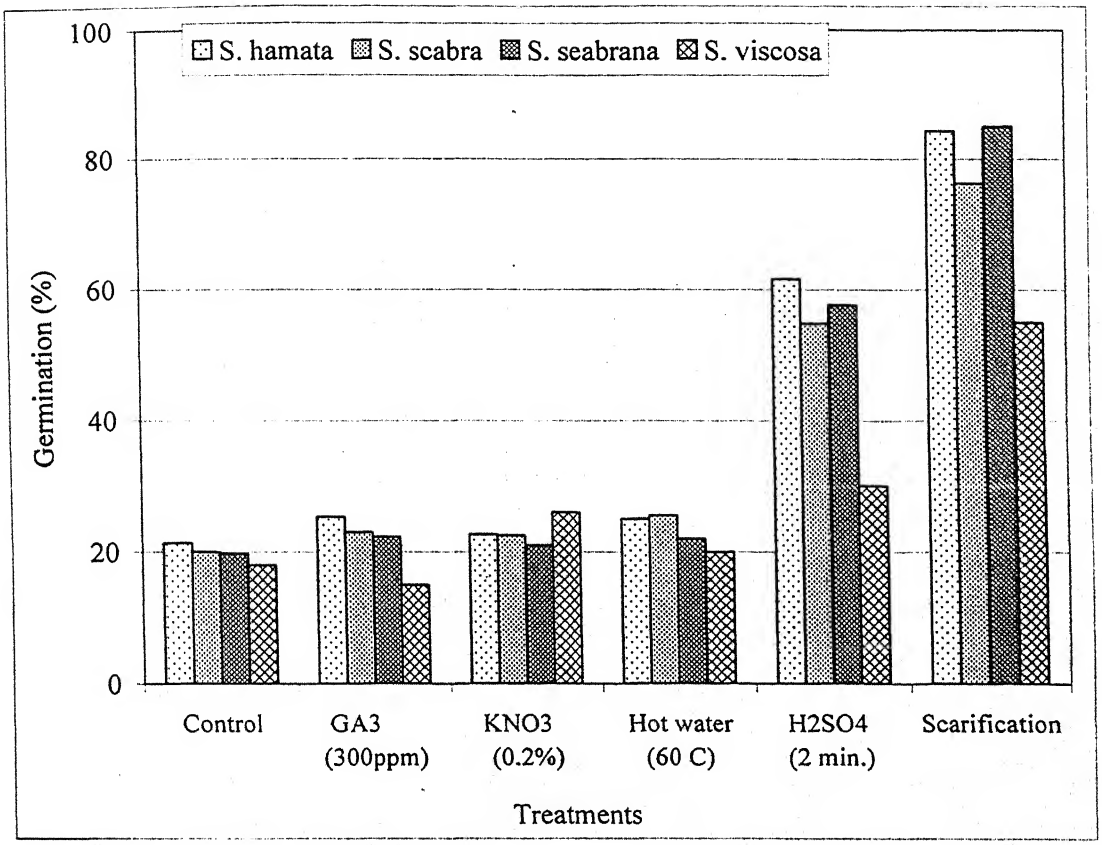


Figure 23. Effect of various treatments on seed germination (%) in different species of *Stylosanthes.*

**(ii) Seedling length**

The seedling length was recorded at the completion of germination after 21 days and data presented in table 21. Highest seedling length was recorded in the seed scarification treatments followed by concentrated $H_2SO_4$ (5 min.), hot water treatment (60°C) and $GA_3$ (300 ppm) and lowest seedling length was recorded in the treatment of $KNO_3$ (0.2%) which was at par with the control. Variation in the seedling length under different treatments including control was also observed among the different genotypes of *Stylosanthes*. Maximum seedling length was recorded in *S. seabrana* (104710) and *S. scabra* (RRR 94-96) followed by *S. scabra* (RRR 94-97) and minimum in *S. hamata* 110123 and *S. viscosa*. In control maximum seedling length was recorded in *S. scabra* (RRR 94-96) followed by *S. hamata* (110135), *S. seabrana* (2539 and 105546 B) and minimum seedling length was recorded in *S. viscosa*.

**(iii) Vigour index**

The vigour index was calculated by multiplying germination percentage with total seedling length and data presented in table 22. As evident from the data the highest value of vigour index was recorded it the scarification treatments and lowest in control. On average of the data of all the genotypes the vigour index improved by 6 fold by the scarification treatments over the control. The maximum vigour index was observed in the seedlings of *S. seabrana* followed by *S. scabra* and *S. hamata* where as lowest value of vigour index was observed in *S. viscosa*. The vigour index also improved to four folds by giving the treatments of concentrate $H_2SO_4$ (5 min), which were effective over other treatments. However, in other treatments the difference in minimum and maximum values was very high but in some genotypes the difference was low. Overall these treatments improved the vigour index.

Table 21. Seedling length (cm) in different genotypes of *Stylosanthes* with different treatments.

| Genotypes | Seedling length (cm) | | | | | |
|---|---|---|---|---|---|---|
| | Control | $GA_3$ (300ppm) | $KNO_3$ (0.2%) | Hot water ($60^{0c}$) | $H_2SO_4$ (5 min.) | Scarification |
| *S. hamata* 110123 | 5.20 | 4.50 | 4.10 | 5.30 | 6.50 | 3.90 |
| *S. hamata* 110135 | 5.60 | 5.10 | 4.10 | 4.80 | 6.30 | 5.40 |
| *S. hamata* 61670 | 3.90 | 4.60 | 2.90 | 5.70 | 5.80 | 4.40 |
| *S. scabra* 36260 | 4.30 | 3.80 | 2.40 | 2.70 | 4.80 | 4.80 |
| *S. scabra* 93116 | 2.60 | 4.40 | 3.50 | 5.20 | 5.80 | 6.90 |
| *S. scabra* cv. fitzroy | 3.90 | 4.90 | 3.80 | 5.40 | 4.80 | 5.40 |
| *S. scabra* cv. seca | 4.00 | 4.80 | 3.30 | 5.70 | 5.80 | 5.90 |
| *S. scabra* q 10042 | 2.40 | 5.20 | 4.30 | 5.60 | 6.30 | 6.0 |
| *S. scabra*RRR 94-100 | 4.30 | 4.10 | 3.10 | 5.80 | 4.80 | 5.80 |
| *S. scabra* RRR 94-86 | 6.10 | 5.90 | 5.30 | 6.20 | 6.40 | 7.20 |
| *S. scabra* RRR 94-93 | 2.90 | 4.40 | 2.00 | 4.40 | 4.30 | 5.60 |
| *S. scabra* RRR 94-97 | 2.20 | 3.80 | 2.90 | 6.70 | 7.40 | 7.80 |
| *S. scabra* RRR 94-96 | 4.10 | 5.10 | 3.80 | 5.90 | 6.90 | 8.00 |
| *S. seabrana* 104710 | 4.20 | 6.40 | 3.20 | 5.40 | 6.00 | 8.10 |
| *S. seabrana* 105546 B | 5.00 | 5.40 | 4.40 | 6.50 | 6.50 | 7.40 |
| *S. seabrana* 110372 | 2.80 | 4.30 | 3.30 | 5.40 | 5.20 | 5.40 |
| *S. seabrana* 2523 | 4.00 | 4.90 | 4.90 | 6.00 | 5.80 | 7.80 |
| *S. seabrana* 2534 | 4.00 | 4.80 | 3.80 | 5.80 | 6.00 | 6.90 |
| *S. seabrana* 2539 | 5.40 | 5.20 | 3.80 | 6.40 | 5.90 | 7.20 |
| *S. viscosa* | 1.80 | 3.90 | 2.70 | 3.60 | 4.70 | 3.90 |
| Average | 3.90 | 4.70 | 3.50 | 5.40 | 5.80 | 6.19 |

Table 22. Vigour index in different genotypes of *Stylosanthes* with different treatments.

| Genotypes | Vigour index | | | | | |
|---|---|---|---|---|---|---|
| | Control | $GA_3$ (300ppm) | $KNO_3$ (0.2%) | Hot water ($60^0$C) | $H_2SO_4$ (5 min) | Scarification |
| *S. hamata* 110123 | 109.20 | 112.50 | 102.50 | 116.60 | 390.00 | 343.20 |
| *S. hamata* 110135 | 156.80 | 132.60 | 102.50 | 168.00 | 346.50 | 459.00 |
| *S. hamata* 61670 | 58.50 | 115.00 | 52.20 | 102.60 | 406.00 | 352.00 |
| *S. scabra* 36260 | 103.20 | 114.00 | 72.00 | 81.00 | 288.00 | 278.40 |
| *S. scabra* 93116 | 26.00 | 88.00 | 42.00 | 114.40 | 290.00 | 621.00 |
| *S. scabra* cv. fitzroy | 7.80 | 117.60 | 83.60 | 108.00 | 153.60 | 432.00 |
| *S. scabra* cv. seca | 128.00 | 182.40 | 132.00 | 313.50 | 435.00 | 495.60 |
| *S. scabra* q 10042 | 48.00 | 78.00 | 77.40 | 112.00 | 252.00 | 420.00 |
| *S. scabra*RRR 94-100 | 129.00 | 123.00 | 77.50 | 116.00 | 192.00 | 435.00 |
| *S. scabra* RRR 94-86 | 170.80 | 106.20 | 190.80 | 217.00 | 448.00 | 561.60 |
| *S. scabra* RRR 94-93 | 46.40 | 79.20 | 24.00 | 88.00 | 172.00 | 392.00 |
| *S. scabra* RRR 94-97 | 22.00 | 45.60 | 43.50 | 100.50 | 562.40 | 608.40 |
| *S. scabra* RRR 94-96 | 41.00 | 127.50 | 57.0 | 106.20 | 448.50 | 640.00 |
| *S. seabrana* 104710 | 84.00 | 115.20 | 64.00 | 118.80 | 372.00 | 745.20 |
| *S. seabrana* 105546 B | 125.00 | 205.20 | 140.80 | 162.50 | 487.50 | 651.20 |
| *S. seabrana* 110372 | 44.80 | 107.5 | 59.40 | 135.00 | 364.00 | 432.00 |
| *S. seabrana* 2523 | 64.00 | 98.00 | 88.20 | 120.00 | 382.80 | 702.00 |
| *S. seabrana* 2534 | 80.00 | 86.40 | 68.40 | 116.00 | 228.00 | 586.50 |
| *S. seabrana* 2539 | 118.80 | 78.00 | 76.00 | 128.00 | 206.50 | 540.00 |
| *S. viscosa* | 18.00 | 58.50 | 70.20 | 72.00 | 141.00 | 214.50 |
| Average | 79.00 | 108.50 | 81.20 | 129.80 | 328.20 | 495.40 |

## 4.2 Effect of foliar applied growth hormones and nutrients on flowering, seed setting, seed yield and quality of seeds in *Stylosanthes hamata.*

### 4.2.1. Plant growth

The effect of foliar applied growth hormone ($GA_3$ (100 ppm), NAA (100 ppm)), nutrients ($KNO_3$ (4 kg/ha) and Boron (100 ppm)) and growth retardant (Cycocel 0.5 kg/ha) on plant height is shown in table 23. Maximum plant height was recorded in the treatment of NAA (100 ppm and minimum in cycocel (0.5 kg/ha). The response of $GA_3$ (100 ppm), $KNO_3$ (4 kg/ha) and Boron (100 ppm ) were at par to the control. On average of the two years data the plant height increased by 8.5% over the control by the foliar application of NAA (100 ppm) where as the plant height decreased by 13% by the application of cycocel (0.5 kg/ha).

### 4.2.2. Branch Production

The number of branches per plant was increased in all the treatments over the control (Table 23). Maximum number of branches was recorded in the plants treated with NAA (100 ppm) and $GA_3$ (100 ppm) and minimum in control plants, whereas, the response as $KNO_3$ (4 kg/ha) and boron (100 ppm) was at par. The response of growth hormone on branching was more effective. In general treatment effect was statistically significant (P 0.05).

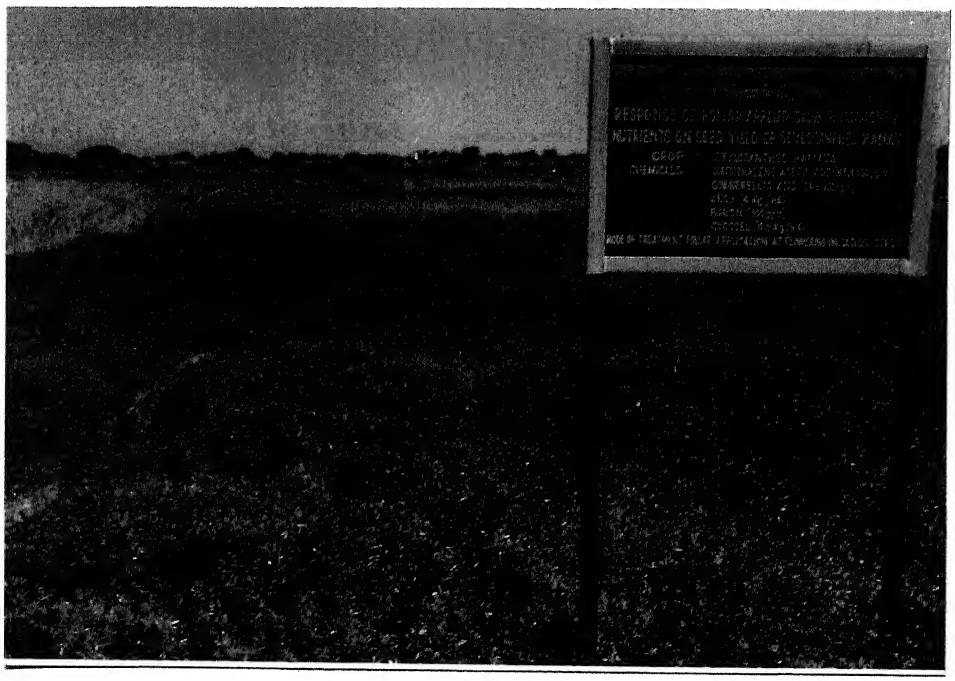

**Plate VII. Response of foliarly applied growth hormones and nutrients on seed yield of *S. hamata*.**

Table 23. Response of foliarly applied growth hormones and nutrients on growth of *S. hamata.*

| Treatments | Plant height (cm) | | | Branches / plant | | |
|---|---|---|---|---|---|---|
| | I Year | II Year | Average | I Year | II Year | Average |
| Control | 37.00 | 35.00 | 36.00 | 9.33 | 11.60 | 10.46 |
| $GA_3$ (100 ppm) | 37.33 | 35.85 | 36.59 | 14.00 | 12.25 | 13.12 |
| NAA (100 ppm) | 39.66 | 38.45 | 39.05 | 13.00 | 13.36 | 13.18 |
| $KNO_3$ (4 kg/ha) | 35.00 | 36.33 | 35.66 | 12.65 | 12.65 | 12.65 |
| Boron (100 ppm) | 38.00 | 35.66 | 36.83 | 13.00 | 12.65 | 12.82 |
| Cycocel(0.5 kg/ha) | 31.00 | 31.66 | 31.33 | 11.66 | 11.66 | 11.66 |
| C D at 5% | 0.92 | 1.43 | - | 1.12 | NS | - |

## 4.2.3. Assimilatory Functions

### (i) Micro environmental parameters

The micro environmental parameter such as photosynthetically active radiation (PAR), air temperature (AT) and relative humidity (Rh) were also recorded at the time of recording the rate of photosynthesis (PN) and rate of transpiration (TR). The mean values of these parameters of both the years are shown in figure 24. The PAR ranged from 1173 to 1259 μ mole/$m^2$/s, RH 29.3% to 33.6% and air temperature 33.11°C to 34.0 °C at the time of recording the observations.

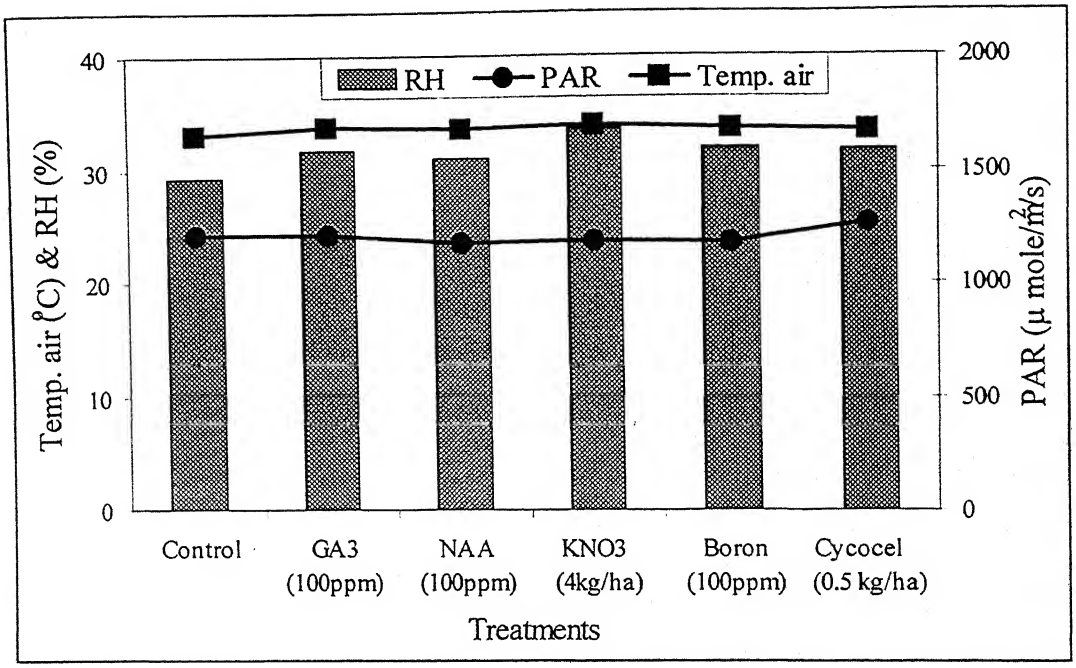


Figure 24. Micro environmental parameters at the time of recording assimilatory parameters in different treatments.

### (ii) **Leaf temperature**

The leaf temperature was also recorded by using the portable photosynthesis system as used for recording the rate of photosynthesis and transpiration. On average of both the years the leaf temperature of treated plants was slightly higher over the control. Maximum leaf temperature was recorded in the leaves sprayed with growth retardants (Cycocel 0.5 kg/ha) followed by boron (100 ppm), whereas, the response of other treatment was at par to the control (Table 25).

### (iii) **Photosynthesis**

The response of foliar applied chemicals was observed on the rate of photosynthesis and data are presented in table 24 and figure 25. In general the rate of photosynthesis increased significantly by the foliar spray of chemicals over the control

during both the years. Maximum rate of photosynthesis was recorded in the plants treated with $GA_3$ (100 ppm) and NAA (100 ppm) followed by $KNO_3$ (4 kg/ha) where as the response of Boron (100 ppm) and cycocel (0.5 kg/ha) were at par. The rate of photosynthesis ranged from 23.03 μ mole/$m^2$/s (control) to 27.59 μ mole/$m^2$/s ($GA_3$ 100 ppm) in the first year and from 23.86 μ mole/$m^2$/s to 29.94 μ mole/$m^2$/s in the second year. On average of both the years the rate of photosynthesis recorded as 28.26 μ mole/$m^2$/s in $GA_3$ (100 ppm) treated plants while it was 23.44 μ mole/$m^2$/s in control plants. The treatments were statistically significant (P 0.05).

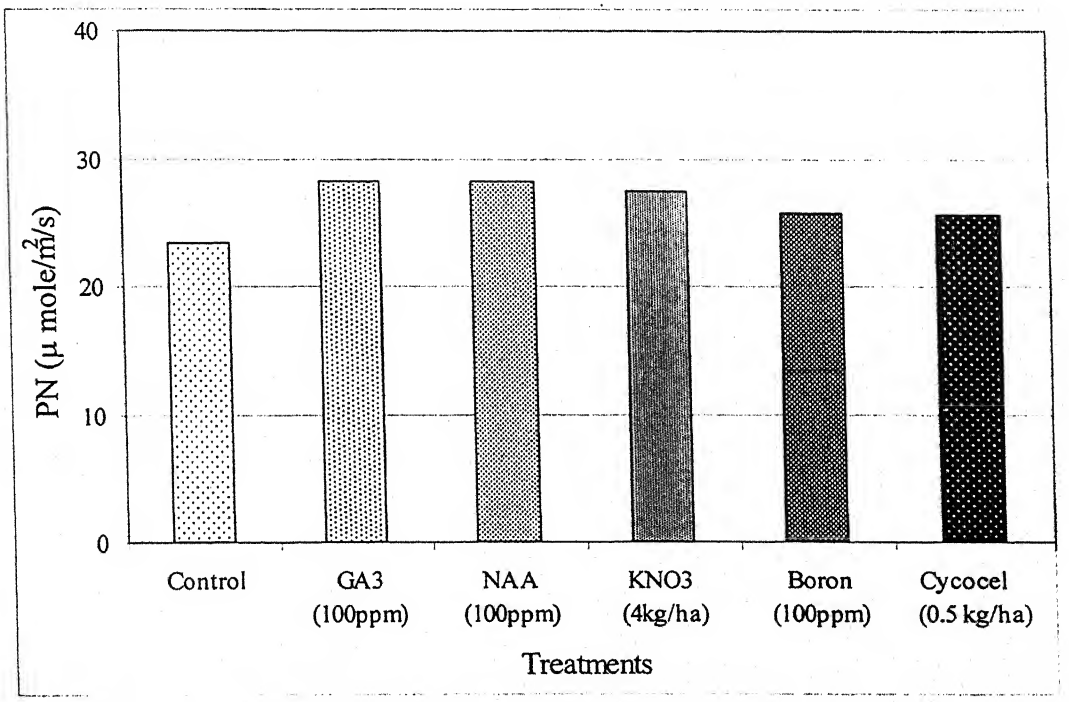


Figure 25. Effect of foliar spray of growth hormones, nutrients and growth retardant on rate of photosynthesis in *S. hamata.*

(iv) **Transpiration**

The rate of transpiration (TR), which indicates the water vapor loss from the leaf surfaces, was recorded at 50% flowering stage and data are presented in table 24 and figure 26. Although no definite trend was observed with respect to the foliar application of growth hormones, nutrients and growth retardant over the control but maximum rate of transpiration was recorded in the plants sprayed with NAA (100 ppm) followed by $KNO_3$ (4 kg/ha). On average of both years' data the rate of transpiration ranged from 12.15 m mole/$m^2$/s ($GA_3$ 100 ppm) to 13.99 μ mole/$m^2$/s (NAA 100 ppm). There was slightly decrease in the rate of transpiration by the foliar application of $GA_3$ (100 ppm), Boron (100 ppm) and Cycocel (0.5 kg/ha).

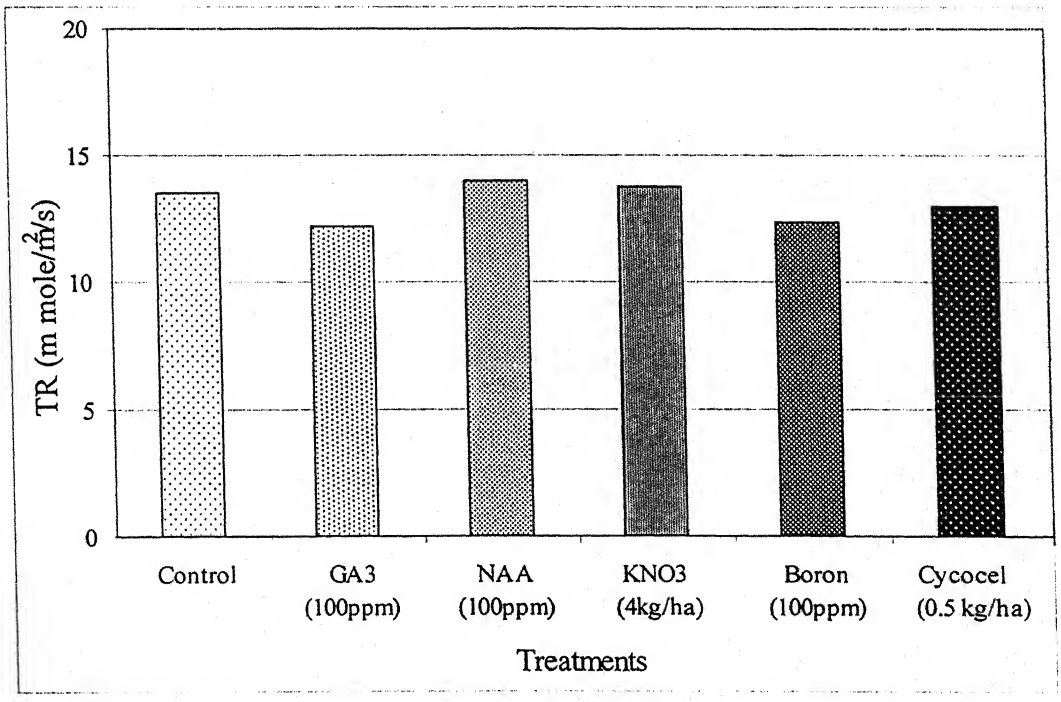


Figure 26. Effect of foliar spray of growth hormones, nutrients and growth retardant on rate of transpiration in *S. hamata*.

## (v) Stomatal Conductance

Similar to the rate of photosynthesis the stomatal conductance increased by the foliar application of chemicals over the control in NAA (100 ppm) treated plant where as it was at par in the $GA_3$ (100 ppm), $KNO_3$ (4 kg/ha) Boron (100 ppm ) and Cycocel (0.5 kg/ha) treatments (table 24 and figure 27). The rate of stomatal conductance was 2.4 $cm^2/s$ in $GA_3$ (100 ppm) treated plants over the control (1.87 $cm^2/s$).

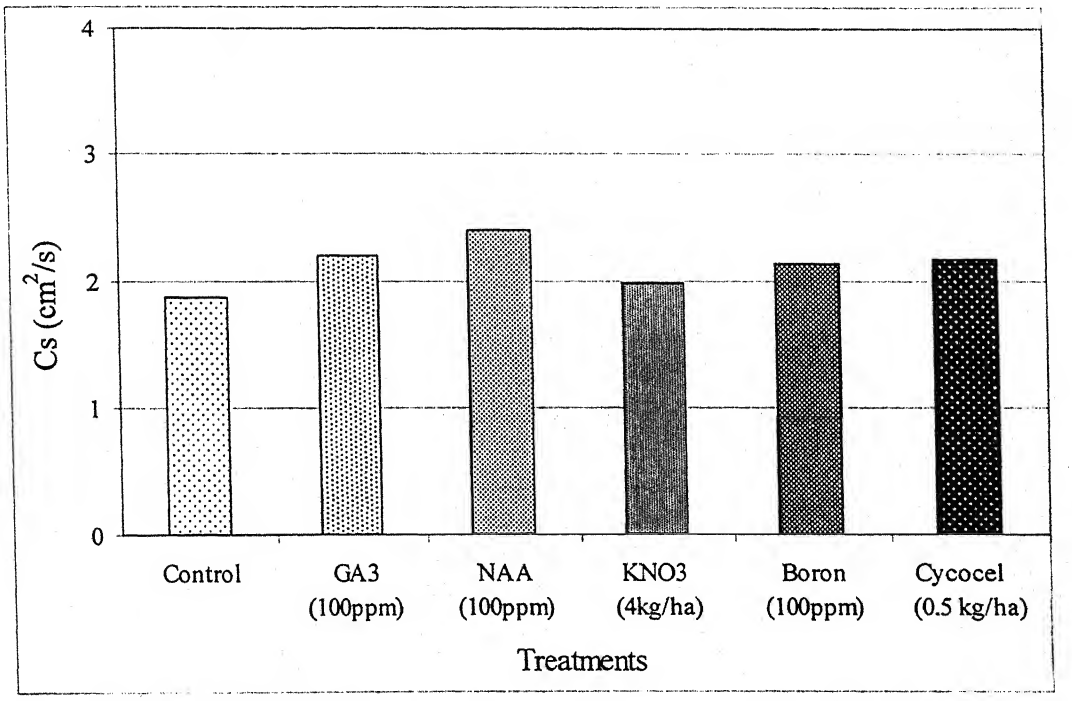


Figure 27. Effect of foliar spray of growth hormones, nutrients and growth retardant on stomatal conductance of *S. hamata*.

Table 24. Effect of foliar spray of growth hormones, nutrients and growth retardant on assimilatory characters of *S. hamata*.

| Treatments | PN (μ mole/$m^2$/s) | | | TR (m mole/$m^2$/s) | | |
|---|---|---|---|---|---|---|
| | Ist Year | IInd Year | Mean | Ist Year | IInd Year | Mean |
| Control | 23.03 | 23.86 | 23.44 | 11.61 | 15.47 | 13.54 |
| $GA_3$ (100 ppm) | 27.59 | 28.93 | 28.26 | 9 .86 | 14.44 | 12.15 |
| NAA (100 ppm) | 26.56 | 29.94 | 28.25 | 11.57 | 16.41 | 13.99 |
| $KNO_3$ (4 kg/ha) | 27.36 | 27.42 | 27.39 | 10.69 | 16.75 | 13.72 |
| Boron (100 ppm) | 24.69 | 26.86 | 25.77 | 10.94 | 13.75 | 12.34 |
| Cycocel (0.5 kg/ha) | 24.87 | 26.86 | 25.62 | 11.45 | 14.46 | 12.95 |
| C. D. at 5% | 0.321 | NS | - | NS | 3.696 | - |

Table cont...

Table cont....

| Treatments | Stomatal conductance ($cm^2/s$) | | |
|---|---|---|---|
| | Ist Year | IInd Year | Mean |
| Control | 1.514 | 2.229 | 1.871 |
| $GA_3$ (100 ppm) | 1.644 | 2.751 | 2.197 |
| NAA (100 ppm) | 1.801 | 3.000 | 2.400 |
| $KNO_3$ (4 kg/ha) | 1.734 | 2.209 | 1.971 |
| Boron (100 ppm) | 1.598 | 2.653 | 2.125 |
| Cycocel (0.5 kg/ha) | 1.738 | 2.598 | 2.168 |
| C. D. at 5% | 0.034 | 0.273 | - |

(vi) **Inter cellular $CO_2$ Concentration**

The data of intercellular concentration is presented in table 25. As evident from the table no definite trend was observed in CINT. However, in the first year the CINT of the control plants was much higher (238.4 ppm) as compared to the other treatments (192 to 216 ppm), whereas, in the second year the highest CINT was recorded in the plants treated with $GA_3$ (100 ppm) followed by $KNO_3$ (4 kg/ha) and Cycocel (0.5 kg/ha). The average data of two years has indicated that these chemicals have not shown any significant effect on inter cellular $CO_2$ concentration.

Table 25. Response of foliarly applied growth hormones and nutrients on leaf temperature ($^{o}$ C) and intercellular $CO_2$ concentration (ppm) of *S. hamata*.

| Treatments | Leaf temperature ($^{o}$ C ) | | | Intercellular $CO_2$ conc.(ppm) | | |
|---|---|---|---|---|---|---|
| | I Year | II Year | Average | I Year | II Year | Average |
| Control | 30.73 | 36.95 | 33.84 | 238.4 | 292.7 | 265.5 |
| $GA_3$ (100 ppm) | 32.92 | 34.88 | 33.90 | 191.9 | 365.5 | 278.7 |
| NAA (100 ppm) | 31.76 | 36.09 | 33.92 | 198.2 | 3 09.8 | 254.0 |
| $KNO_3$ (4 kg/ha) | 32.70 | 35.00 | 33.85 | 199.9 | 356.1 | 278.0 |
| Boron (100 ppm) | 32.75 | 35.44 | 34.09 | 216.6 | 272.7 | 244.4 |
| Cycocel(0.5 kg/ha) | 32.19 | 36.37 | 34.28 | 216.1 | 335.1 | 275.6 |
| C. D. at 5% | NS | NS | - | 5.60 | 6.71 | - |

**(vii) Carboxylation efficiency**

The ratio of photosynthesis per intercellular $CO_2$ concentration (PN/ CINT) represent the carboxylation efficiency was found to the maximum in

plants treated with growth hormones, nutrients and growth retardant (Table 26). In the first year the carboxylation efficiency was more than to the second year of experiment. On average of both the years maximum carboxylation efficiency was observed in the treatment of NAA (100 ppm) followed by $GA_3$ (100 ppm) and minimum in control plants.

**(viii) Water use efficiency**

The ratio of photosynthesis per transpiration (PN/TR) indicates the water use efficiency and was found to be maximum in the plants treated with $GA_3$ (100 ppm) and minimum in control (Table 26). The water use efficiency was at par in other treatments. The water use efficiency was recorded high in the first year as compared to the second year. The data indicates that foliar application of hormone has improved the photosynthetic water use efficiency of *S. hamata.*

Table 26. Response of foliarly applied growth hormones and nutrients on carboxylation efficiency and water use efficiency of *S. hamata.*

| Treatments | Carboxylation efficiency (PN/CINT) | | | Water use efficiency (PN/TR) | | |
|---|---|---|---|---|---|---|
| | I Year | II Year | Average | I Year | II Year | Average |
| Control | 0.096 | 0.081 | 0.088 | 1.98 | 1.54 | 1.76 |
| $GA_3$ (100 ppm) | 0.140 | 0.079 | 0.109 | 2.79 | 2.00 | 2.40 |
| NAA (100 ppm) | 0.130 | 0.096 | 0.113 | 2.29 | 1.82 | 2.06 |
| $KNO_3$ (4 kg/ha) | 0.130 | 0.074 | 0.102 | 2.55 | 1.57 | 2.06 |
| Boron (100 ppm) | 0.110 | 0.098 | 0.104 | 2.25 | 1.95 | 2.10 |
| Cycocel(0.5 kg/ha) | 0.110 | 0.087 | 0.098 | 2.17 | 2.03 | 2.10 |
| C. D. at 5% | 0.011 | 0.002 | - | 0.236 | 1.885 | - |

## 4.2.4. Flowering, seed yield and seed test weight

### i) Flowering behavior

The flower number/ plants at the time of maximum flowering was recorded and data presented in table 26 and figure 28. The flower production increased significant by the foliar application of growth hormones and nutrients over the control. On average of both the years maximum number of flowers were recorded in the plants treated with $GA_3$ (100 ppm) where as the response of NAA (100 pm), $KNO_3$ (4 kg/ha) and Boron (100 ppm) was at par. The flower production ranged from 436 to 914 in the first year and 520 to 826 in the second year in the control and $GA_3$ application respectively. The results revealed that flowering production and synchronization of flowering were also significantly improved by the application of these chemical over the control.

Table 26. Response of foliarly applied growth hormones and nutrients on flower No. / plant of *S. hamata.*

| Treatments | Flower No. / plant | | |
|---|---|---|---|
| | I Year | II Year | Average |
| Control | 436.00 | 520.00 | 478.00 |
| $GA_3$ (100 ppm) | 914.00 | 826.00 | 870.00 |
| NAA (100 ppm) | 577.00 | 712.00 | 644.50 |
| $KNO_3$ (4 kg/ha) | 572.00 | 775.00 | 673.50 |
| Boron (100 ppm) | 587.00 | 735.00 | 661.00 |
| Cycocel (0.5 kg/ha) | 486.00 | 550.00 | 518.00 |
| C. D. at 5% | 49.53 | 69.55 | - |

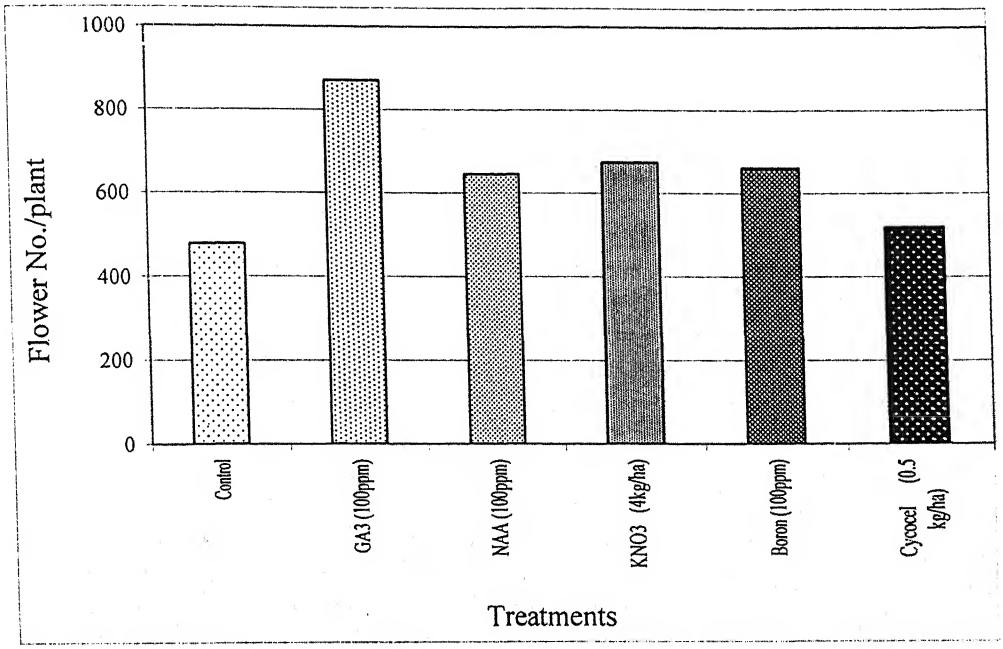


Figure 28. Effect of foliar spray of growth hormones, nutrients and growth retardant on flowering in *S. hamata.*

**ii) Seed yield**

The seed yield of *S. hamata* was significantly increased by the foliar application of chemicals (growth hormones, nutrients and growth retardants) and data are presented in table 27 and figure 29. The seed yield ranged from 119 kg/ha to 178.25 kg/ha in the first year and 220.40 kg/ha to 286.98 kg/ha in the second year in control and foliar application of $GA_3$ (100 ppm) respectively. On average of the two years data maximum seed yield was recorded in the plants treated with $GA_3$ (100 ppm) (232.61 kg/ha) followed by $KNO_3$ (4 kg/ha) (215.65 kg/ha). Where as the treatments of NAA (100 ppm) and Boron (100 ppm) were at par. Over all seed yield increased by 2.4% to 37% over the control (169.70 kg/ha) by the foliar application of these chemical as applied at vegetative and flowering initiation stage of the plant growth. The treatments were statistically significant at P 0.05.

Table 27. Response of foliarly applied growth hormones and nutrients on seed yield of *S. hamata.*

| Treatments | Seed yield (kg/ha) | | |
|---|---|---|---|
| | I Year | II Year | Average |
| Control | 119.00 | 220.40 | 169.70 |
| $GA_3$ (100 ppm) | 178.25 | 286.98 | 232.61 |
| NAA (100 ppm) | 125.50 | 278.53 | 202.01 |
| $KNO_3$ (4 kg/ha) | 164.75 | 266.55 | 215.65 |
| Boron (100 ppm) | 156.75 | 258.66 | 207.70 |
| Cycocel (0.5 kg/ha) | 121.50 | 226.16 | 173.83 |
| C. D. at 5% | 2.44 | 4.55 | - |

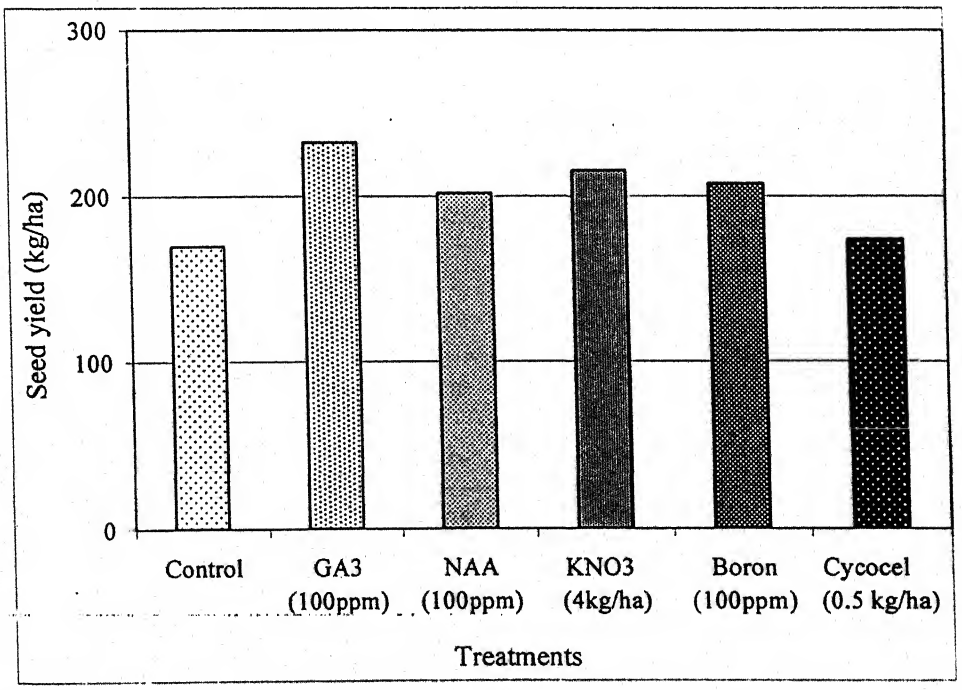


Figure 29. Effect of foliar spray of growth hormones, nutrients and growth retardant on seed yield (kg/ha) in *S. hamata.*

### iii) Seed Test weight

The seed quality in term of seed test weight (one thousand seed weight) was also improved by the foliar application of these chemicals, over the control (table 28 figure 30. The maximum seed test weight was recorded by the foliar application of $KNO_3$ (4 kg/ha) (3.26 g) followed by $GA_3$ (100 ppm) (3.22g). On average of both the years the seed test weight ranged from 2.85 gm (control) to 3.26 gm ($KNO_3$, 4 kg/ha). The seed test weight of seeds produced from the cycocel (0.5 kg/ha) treated plants was equal to the control. The treatments were statistically significant at P 0.05.

Table 28. Response of foliarly applied growth hormones and nutrients on seed test weight of *S. hamata.*

| Treatments | 1000 seed wt. (g) | | |
|---|---|---|---|
| | I Year | II Year | Average |
| Control | 2.65 | 3.05 | 2.85 |
| $GA_3$ (100 ppm) | 3.30 | 3.14 | 3.22 |
| NAA (100 ppm) | 3.22 | 3.08 | 3.15 |
| $KNO_3$ (4 kg/ha) | 3.36 | 3.16 | 3.26 |
| Boron (100 ppm) | 3.10 | 2.99 | 3.05 |
| Cycocel (0.5 kg/ha) | 2.68 | 3.05 | 2.86 |
| C. D. at 5% | 0.23 | NS | - |

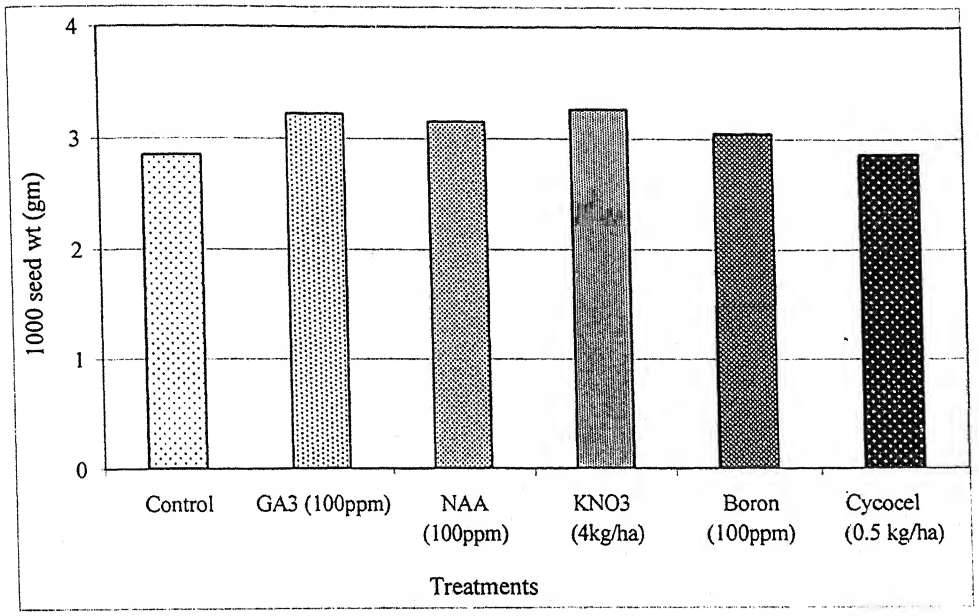


Figure 30. Effect of foliar spray of growth hormones, nutrients and growth retardant on seed test weight (g) in *S. hamata*.

# 5

# Discussion

## I. Growth behavior, morphophysiological characters, seed yield and germination in different genotypes of *Stylosanthes*

The twenty genotypes of four species of *Stylosanthes* (*S. hamata*, *S. scabra*, *S. seabrana* and *S. viscosa*) was studies for two years for their growth, morphological and physiological functions under rainfed condition in semi arid environmental condition. Looking the growth in term of height increment of different genotypes during both the years the *S. scabra* cv *seca* and *S. seabrana* 110372 attend the maximum growth whereas *S. hamata* 110135 recorded the minimum plant height. The genotypic difference has been clearly observed between the genotypes of *S. scabra*, *S. seabrana*. *S. hamata* and *S. viscosa*. The genotypes of *S. scabra* were large in height growth indicating their bushy nature whereas the genotypes of *S. seabrana* were medium in height and the genotypes of *S. hamata*, *S. viscosa* were lower in height increment occurring as creeper.

The magnitudes of dependence on plant height increment of the various growth morphological and physiological functions were positive as indicated by the values of correlation coefficient (Table 29). However, as apparent that plant height is strongly dependent on stem diameter, leaf area, rate of photosynthesis. This higher correlation between leaf area and extension growth was also reported by various workers i.e., Watson, 1947, Muramato *et. al.*, 1965, Duncan and Hesketh, 1968 and Hanson, 1972. The maximum elongation of root was found in *S. seabrana* 110372 followed by *S. scabra* q 10042 and minimum in *S. hamata* 110135. However, maximum number of genotypes was at par in their root growth. The root growth in all the genotypes of *Stylosanthes* species is synchronized with the shoot growth as apparent from the positive and significant correlation between plant height and root length (r = 0.5291) (Table 29). Root length was also found to be strongly correlated with stem diameter, total biomass production, leaf area, and specific leaf weight. These results are confirmatory to the findings of (Vandana, 1996) in *Sesbania* species.

The plant girth increment which was recorded as stem diameter has also shown genotypic variability which ranged from 0.51 cm to 0.79 cm. *S. scabra* cv *seca* has attended maximum stem diameter. The data revealed that the genotypic variability exists among the species of *Stylosanthes* but the variability is narrow among the genotypes of *S. scabra* and *S. seabrana*. Narrow variability was observed in branch production per plant in the genotypes of *Stylosanthes*. Large variability was observed in leaf length and width among the genotypes of *S. hamata*, *S. scabra*, *S. seabrana* and *S. viscosa*. On perusal of the data the variability in the leaf width was more then the leaf length as indicated by the statistically significant data at P 0.05.

The total fresh biomass production which include the above ground (leaves + stem + branches) and bellow ground (roots) was found to be maximum in genotypes of *S. scabra* followed by the genotypes of *S. seabrana*, S. viscosa and minimum in *S. hamata*. The genotypes of *S. scabra* RRR 94-100 produced maximum biomass among all the genotypes followed by *S. scabra* q 10042, *S.*

*scabra* RRR 94-97, *S. scabra* RRR 94-96. Among the genotypes of *S. seabrana* accession 110372, produced maximum biomass. In the genotypes of *S. hamata* accession 110135 produced maximum fresh biomass. Among all the genotypes the

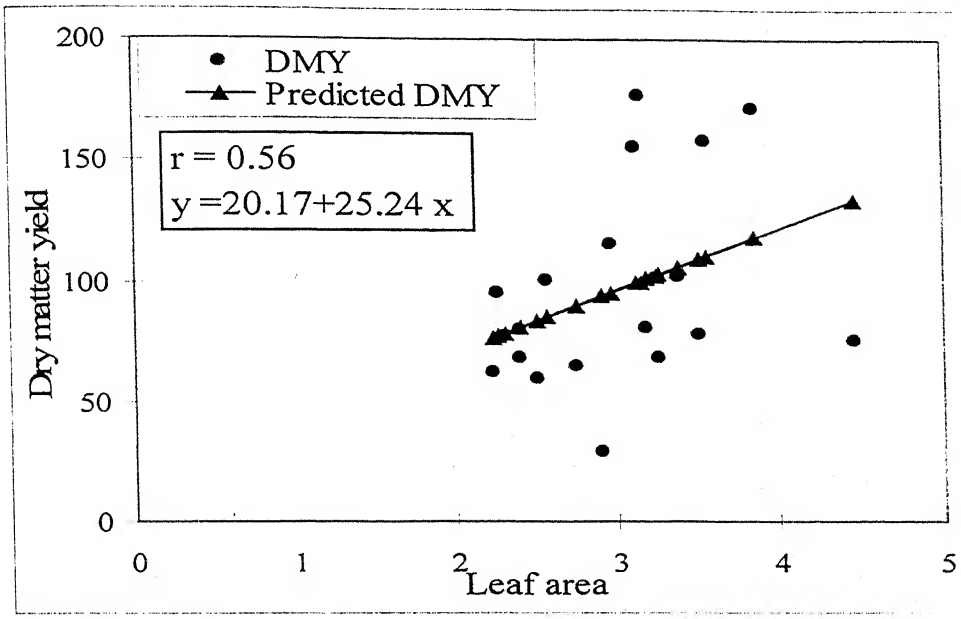


Figure 31. Relationship between Dry matter yield (DMY) and leaf area in Different genotypes of *Stylosanthes*.

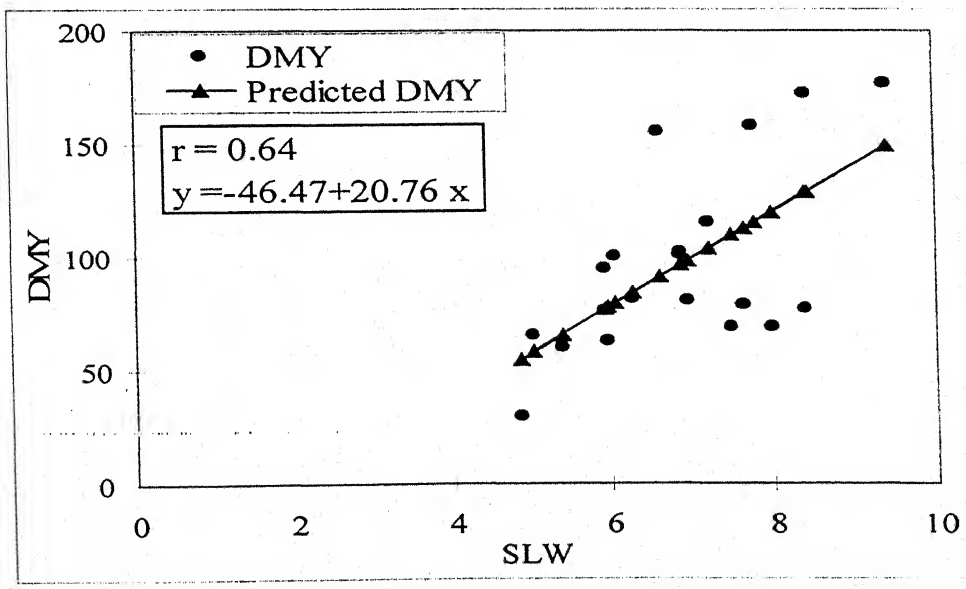


Figure 32. Relationship between Dry matter yield (DMY) and specific leaf weight (SLW) in different genotypes of *Stylosanthes*.

Table 29. Correlation coefficient among various assimilatory and physiological characters.

| | Plant height | Root length | Plant diameter | Total fresh wt. | Total dry wt. | Leaf area | SLW | SLA | PN | TR | Cs |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height | 1.0000 | | | | | | | | | | |
| Root length | 0.5291 | 1.0000 | | | | | | | | | |
| Plant diameter | 0.6961 | 0.2310 | 1.0000 | | | | | | | | |
| Total fresh wt. | 0.4820 | 0.4176 | 0.5212 | 1.0000 | | | | | | | |
| Total dry wt. | 0.5039 | 0.3795 | 0.5304 | 0.9467 | 1.0000 | | | | | | |
| Leaf area | 0.3784 | 0.3513 | 0.3125 | 0.6349 | 0.6360 | 1.0000 | | | | | |
| SLW | 0.4600 | 0.4910 | 0.5865 | 0.7294 | -0.5215 | 0.3873 | 1.0000 | | | | |
| SLA | -0.5296 | -0.3687 | -0.6475 | -0.6362 | 0.0575 | -0.4100 | -0.8904 | 1.0000 | | | |
| PN | 0.3856 | 0.1515 | 0.4402 | 0.1878 | -0.0727 | 0.1688 | 0.1996 | -0.2539 | 1.0000 | | |
| TR | 0.1916 | 0.2155 | 0.2114 | 0.0514 | -0.0065 | -0.0616 | 0.2927 | -0.3527 | 0.4774 | 1.0000 | |
| CS | 0.2274 | 0.1259 | 0.1052 | -0.1023 | -0.0876 | -0.1062 | 0.0228 | -0.1592 | 0.5791 | 0.6812 | 1.0000 |
| CRITICAL VALUE (1-TAIL, .05) = + Or - 0 .37911<br>CRITICAL VALUE (2-tail, .05) = +/- 0.44260 | | | | | | | | | | | |

minimum biomass production was recorded in *S. hamata* 110123. The fresh biomass production has indicated the green forage production potential of the genotypes under semi arid environment.

Similar to the fresh biomass the dry biomass production of above and bellow ground parts was recorded maximum in *S. scabra* RRR 94-100 followed by *S. scabra* q 10042 among the genotypes of *S. scabra* whereas *S. seabra*na 110372 and *S. hamata* 110123 have been selected as high dry biomass producing genotypes among the genotype of *S. seabra*na and *S. hamata* respectively. Dry matter production was found to be positively and significantly correlated with plant height, root length, stem diameter, leaf area and specific leaf weight revealing the simultaneous growth of all the plant parts (Table 29).

The strong and lenear relationship of dry matter yield with leaf area indicates the dependent of biomass production on the assimilatory surface area (Figure 31). The dry matter yield was also positively and significantly correlated with specific leaf weight ($r = 0.64$) (Figure 32).

During the second year the fresh and dry biomass production of all the genotypes was observed much higher than the first year which is due to regeneration of the first year harvested plants. The higher growth and biomass production of different genotypes has indicated the regeneration potentiality over the year and therefore, recommended for the sustainable biomass production in different cropping systems.

Being the forage species the maximum biomass partitioning was observed in the above ground parts (leaves + stem + branches), which ranges from 92.2% to 95.7%. The partitioning of the biomass in the above ground parts had indicated that all the genotypes are potential for higher biomass production. The genotypes indicating relatively higher biomass partitioning to the root can be considered as high regenerating genotypes.

The leaf area production, which was recorded, of 50% flowering stage indicated higher leaf area expansion growth in *S. scabra* cv *seca* and minimum in *S. seabrana* 2523. Large variability has been observed in leaf area among the different genotypes of *Stylosanthes*. The specific leaf weight, which represents the average leaf dry weight per unit leaf area, is found to be maximum *S. scabra* RRR 94-100 followed by *S. scabra* q 10042. *S. seabrana* 2539 indicating their high biomass production potential under the rainfed semi arid environmental conditions. The genotypes which has indicated their superiority over the other genotypes with regards to the SLW were observed to be maximum in the genotypes *S. scabra* and *S. seabrana*.

The specific leaf weight was positively and strongly correlated with all the growth, morphological, biomass and physiological characters (Table 29) exhibiting its role in growth and biomass production potential of genotypes. The specific leaf area in considered to be a messure of the environmental influence on the leaf area expention (Evans, 1972). Although most of the genotypes of different species of *Stylosanthes* were at par in their specific leaf area but the genotypes *S. scabra* 36260 and all the genotypes of *S. hamata* were higher in the specific leaf area.

The microenvironmental parameters such as relative humidity (RH), air temperature (AT) and Photosynthetically active radiation (PAR) were also recorded at the time of taking the observation on assimilatory character of the leaves. On an average of different observation the RH was 32% and 35%, air temperature 31.64 and 38.80 $^{0}$C and PAR 1200 and 1323 μ mole/m$^{2}$/sec during the first and second year respectively. The micro environmental parameters indicate that all the observation pertaining to the assimilatory processes and physiological activities were measured at optimum conditions in all the genotypes of *Stylosanthes*. The genotypic variability in the leaf temperature ranges from 30.99 $^{0}$C to 34.12 $^{0}$C this variability exists due to the leaf morphology, shape and size and rate of transpiration. The leaf temperature is also species dependent as reported by (Vandana and Bhatt, 1999, Lange, 1965, Bhatt *et. al.*, 1991).

Taking in to consideration the assimilatory functions that different genotypes of *Stylosanthes* during both the years we found the variation from, 19.65 to 27.67 μ mole/$m^2$/Sec. The maximum rate of photosynthesis was observed in *S. scabra* cv *Seca* followed by *S. seabrana* 2534 indicating their higher $CO_2$ assimilation potentiality and therefore, the genotype should be selected for further improvement program for the high $CO_2$ assimilation towards leading to mitigation of elevated $CO_2$, in the atmosphere under semi arid tropical environmental condition. Similarly variation in photosynthesis has also been reported for a variety of plant species (Strain *et. al.*, 1976, Bhatt, 1989, Vandana and Bhatt, 1999). The rate of photosynthesis is positively correlated with rate of transpiration, stomatal conductance and PN/CINT ratio indicating the inter dependence of these characters (Table 30). The rate of photosynthesis was also found positively correlated with plant height, root length, stem diameter, total dry weight, leaf area and SLW as indicated by their correlation coefficient as depicted in table 29. The significant and positive correlation coefficient and linear regression between rate of photosynthesis and stomatal conductance is indicating the fact that assimilation of $CO_2$ is strongly dependent on the stomatal functional i.e. stomatal conductance (Figure 33).

Photosynthesis is a prerequisite for biomass production and its subsequent partitioning to economically important parts to obtained higher yield. It is well known fact that a higher rate of photosynthesis is always associated with higher productivity, unless sink capacity is limiting (Yoshida, 1972). Similar to our findings a wide variation in leaf photosynthesis rate has been reported among the genotype of pea (Armstong and Pate, 1994), Soybean (Kokuban *et. al.*, 1988), Rice (Basuchaudhuri and Dasgupta, 1987), Wheat (Kumar *et. al.*, 1998), Cotton (Timmannavar and Patial, 2000) and Barnyard millet (Kumar *et. al.*, 2000).

The process of transpiration, which is known to be important in controlling to the leaf temperature in all the genotypes. $CO_2$ assimilation and water use efficiency was prominent in all the genotypes. The genotypic variability in the rate of transpiration ranges from of 8.40 to 13.33 μ mole/$m^2$/sec being maximum in *S.*

*scabra* RRR 94-93 followed by *S. seabrana* 110372 and *S. scabra* 93116. The minimum rate of transpiration was observed in some of the genotypes of *S. hamata* 110135, *S. hamata* 61670 and some of the genotypes of *S. scabra* indicating their tolerance to high soil moisture stress and should be recommended for the cultivation in the dry zones of the country. The significant correlation of transpiration rate with the growth, parameter. (Table 29) and assimilatory character (Table 30) indicates its major role in water relation process of the growth and development of a genotype. The rate of transpiration is strongly dependent on the stomatal conductance as indicated by leaner regression between these two parameters (Table 34). The rate of transpiration was maximum at higher temperature and PAR as also reported by Haseba *et. al.*, (1967) and Bhatt (1990).

The $CO_2$ assimilation is the process of photosynthesis and water vapour transfer is the process of transpiration are directly related to the stomatal conductance (Table 32 and 34). The genotypic variability in the stomatal conductance ranged from 0.58 to 1.12 sec./cm indicating that there is variability in the stomatal structure and functioning. *S. seabrana* 2534 and *S. scabra* cv. seca showed the maximum stomatal conductance indicating their high $CO_2$ assimilation leading towards the more biomass production and therefore, should be selected for further improvement programme. However, no definit trend was observed in the intercellular $CO_2$ concentration in different genotypes of *Stylosanthes* during both the years of experimentation.

The carboxylation efficiency (a ratio of PN/CINT, Farquhar and Sharkey 1982) was calculated maximum in *S. scabra* cv. *Seca* and *S. scabra* RRR 94-100 and *S. seabrana* 2534 indicating their higher potentiality towards the $CO_2$ fixation. This character which ultimately influences the $CO_2$ assimilation, photosynthetic rate and PN/CINT ratio are positively correlated as was reported by Dejong *et. al.*, 1984. The water use efficiency (a ratio PN/TR), which is intimately associated with the a loss of water vapour from the leaf surface to the atmosphere was found to be highest in *S. scabra* RRR 94-100 followed by *S. hamata* 61670 indicating their high water use efficiency.

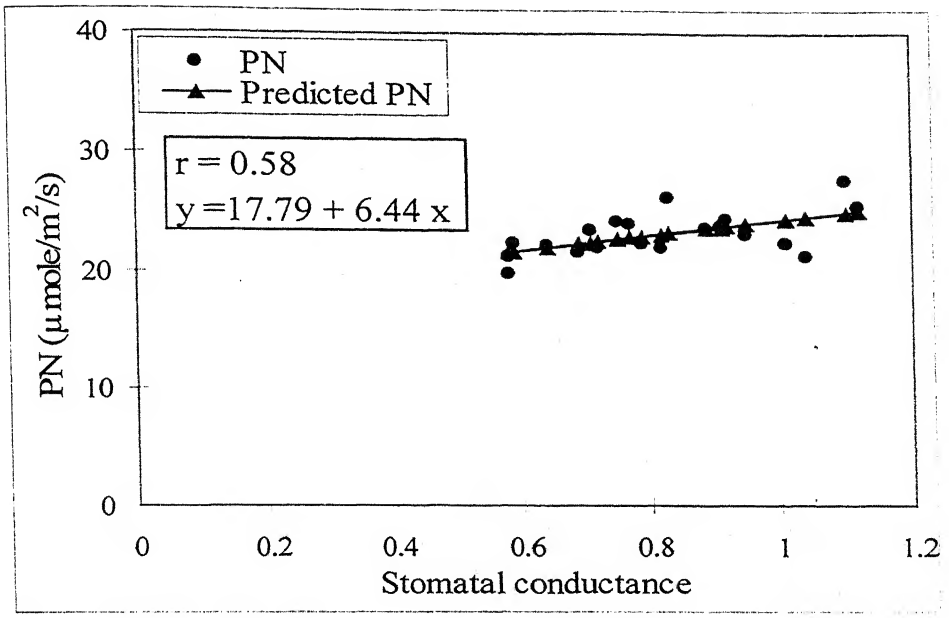


Figure 33. Relationship between rate of photosynthesis (PN) and stomatal conductance in different genotypes of *Stylosanthes*.

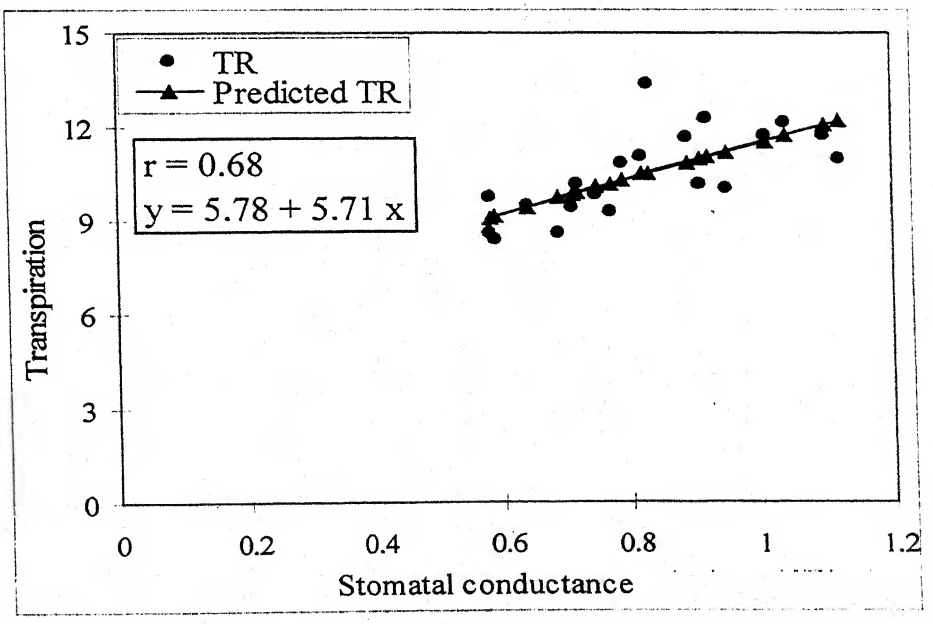


Figure 34. Relationship between rate of transpiration (TR) and stomatal conductance in different genotypes of *Stylosanthes*.

Table 30. Correlation coefficient among various assimilatory and physiological characters.

| | LT | PN | TR | CS | CINT | PN/CINT | PN:TR | Chl a+b | Chl a:b | Sugar | CP |
|---|---|---|---|---|---|---|---|---|---|---|---|
| LT | 1.0000 | | | | | | | | | | |
| PN | -0.0878 | 1.0000 | | | | | | | | | |
| TR | -0.0829 | 0.4774 | 1.0000 | | | | | | | | |
| CS | -0.1279 | 0.5791 | 0.6812 | 1.0000 | | | | | | | |
| CINT | -0.1690 | -0.3904 | -0.0923 | -0.1841 | 1.0000 | | | | | | |
| PN/CINT | 0.2019 | 0.7445 | 0.2438 | 0.4656 | -0.7807 | 1.0000 | | | | | |
| PN:TR | 0.0134 | -0.1381 | -0.8104 | -0.5310 | 0.0756 | -0.0878 | 1.0000 | | | | |
| Chl a+b | 0.4420 | -0.1028 | -0.4278 | -0.4161 | 0.0845 | 0.0066 | 0.3713 | 1.0000 | | | |
| Chl a:b | -0.2028 | -0.3674 | -0.5063 | -0.1241 | 0.4582 | -0.3594 | 0.2665 | 0.2992 | 1.0000 | | |
| Sugar | -0.1683 | 0.4410 | 0.1226 | 0.3862 | -0.3568 | 0.5320 | -0.1137 | -0.1114 | 0.1665 | 1.0000 | |
| CP | 0.0945 | -0.6552 | -0.5051 | -0.4169 | 0.5024 | 0.5589 | 0.3924 | 0.1774 | 0.6039 | -0.2025 | 1.0000 |

CRITICAL VALUE (1-TAIL, .05) = + Or - .37911
CRITICAL VALUE (2-tail, .05) = +/- .44260

The accumulation of photosynthetic pigments (Chl.a, Chl.b, Chl.a+b and Chl a:b) depends on the growth stage of genotypes and surrounding environmental conditions. The genotypic variability in the accumulation of chlorophyll a ranges from 0.58 to 1.30 mg/g and Chl.b it ranges from 0.19 to 0.38 mg/g fresh weight. The total chlorophyll accumulation was estimated to be highest in *S. seabrana* 104710. The chlorophyll a:b was calculated maximum in the genotypes of *S. hamata* which may be due to low accumulation of chlorophyll b. The chlorophyll a+b and chlorophyll a:b are positively correlated with water use efficiency (PN/TR) as indicated in the table 30. The genotypic variability was observed more in the accumulation of chlorophyll b as compared to the chlorophyll a. The Chlorophyll a:b indicates the photosynthetic efficiency of plants which decreases with increase of SLW (Bhatt and Sinha, 1990) as indicated by the negative correlation coefficient between these two parameters (r = -2188).

Genotypic variability in the nitrate reductase activity of different genotypes ranges from 218.37 to 600.28 μ mole nitrite/g fresh weight/hour. As perusal of the data of NRA of the genotypes of *S. scabra* and *S. seabrana* indicates that all the genotypes are almost in narrow range with respect to their NR activity. The genotypes of *S. hamata* have shown at par in their NR activity. *S. viscosa* which having only one genotypes has shown the highest NR activity which is 2 to 3 fold to other genotypes of *S. scabra*, *S. seabrana* and *S. hamata*. This indicates its intrinsic property towards higher NR activity may be leading to higher nitrogen assimilation. The genotypic variability in the accumulation of sugar content ranges from 10.71 to 33.93 mg/g dry weight. *S. scabra* cv seca, *S. seabrana* 104710 and *S. seabrana* 2534 has indicated the maximum accumulation of water soluble sugar in the leaf exhibiting their better fodder quality as energy supplement to the livestock. Large variability exists in the crude protein content (13.91 to 18.26%) in different genotypes of *Stylosanthes*.

The higher crude protein content in all the genotypes of *S. hamata*, *S. viscosa*, *S. scabra* cv Fitzroy, *S. scabra* q 10042 and *S. seabrana* 2534 and *S. seabrana* 105546 B indicating their rich source of protein supplement to the

animals, therefore, these genotypes should be selected for further quality improvement programme in *Stylosanthes*.

Looking the flowering behavior of different genotypes of all the four species of *Stylosanthes* which has exhibited the non-synchronized nature of flowering. The genotypes of *S. hamata*, *S. seabrana* and some genotypes of *S. scabra* (*S. scabra* cv. fitzroy, *S. scabra* RRR 94-97) were early flowering genotypes whereas most of the genotypes of *S. scabra* were late flowering types. In general the flowering duration ranges from 67 days to 130 days indicating that there is long flowering span which lead to the non-synchronized seed maturation in this crop. Due to the non synchronized nature of flowering the seed setting and seed maturation was also varied in different genotypes, this has lead to the continuous collection of the seeds. The non synchronized nature of flowering has also leads to seed shettering in this crop.

Looking the seed morphology that each and every seed bears a prominent and curved hooks. It is highly hooked in *S. hamata* and small hook in *S. scabra* and *S. seabrana*. The seed coats are dark brown in case of *S. scabra* and *S. hamata* wherein whitish in case of *S. seabrana*.

Thc genotypes of the *S. seabrana* (*S. seabrana* 2534 and 2523) were selected as high seed yielder genotypes whereas the genotypes the *S. hamata* were comparatively low seed yielder. In the first year their was low seed production as it was the establishment year but during the second year the genotypes of *S. scabra* and *S. seabrana* regenerated and produced maximum seed yield. Large variability exists in the seed production in different genotypes of *Stylosanthes*. Therefore, it is recommended that genotypes of *S. seabrana* should be selected as high seed yielder genotypes for the semi arid tropical environment.

Seed germination in *Stylosanthes* has been a problem because of physical dormancy. There are many factors responsible for seed germination, establishment and growth. *Stylosanthes hamata* is a small seeded crop have been high proportion of hard seed coat which is described at exogenous dormancy and can reduce the establishment of this species resulting in to an uneven seed germination. The seeds, which were generally sown in the month of July, only 20 to 30% germinated in the first year and rest of the seeds remain as such in dormant stage and germinated during the second and third year. The seeds remain dormant even for more than one year in the soil. Therefore, to improve the seed germination it is necessary to break the seed dormancy either through mechanical or chemical treatment. These methods are widely used for obtaining synchronized germination of seeds. Seeds of *Stylosanthes* developed different degree of hardness but when seed moisture falls below (7%) all seeds showed exogenous dormancy. Cameron (1997) also noted difference n the degree of exogenous dormancy into consecutive years for 25 lines of *Stylosanthes* families grown in the same locality, attributing these differences to environmental factors. It has been reported by various workers that the seed coat hardness is because of seed polymorphism due to genetic as well as environmental factor. The seed hardness was also correlated with the position of the seeds in pods in the basal and / or top region in inflorescence.

Germination of untreated seed is generally very low and therefor, some dormancy breaking treatments are essential to get the better field establishment. To ensure the rapid and uniform seed emergence, pre-sowing treatments of hot water ($60^0$C), $KNO_3$ (0.2%), concentrate $H_2SO_4$ (5 minute), $GA_3$ (300ppm) and scarification through course sand paper were tested in the seeds of different genotypes of *Stylosanthes*. Promising results were achieved by the seed scarification treatments and about 79% germination was obtained over control (19%). Whereas in some of the genotypes about 85 to 92% germination was achieved. Seed treatment of concentrated $H_2SO_4$ and then washing in tap water for 15 minutes has also significantly improved the seed germination whereas the other treatments were at par. Scarification seed treatments for dormancy breaking in different genotypes of *Stylosanthes* is the easiest and feasible method and

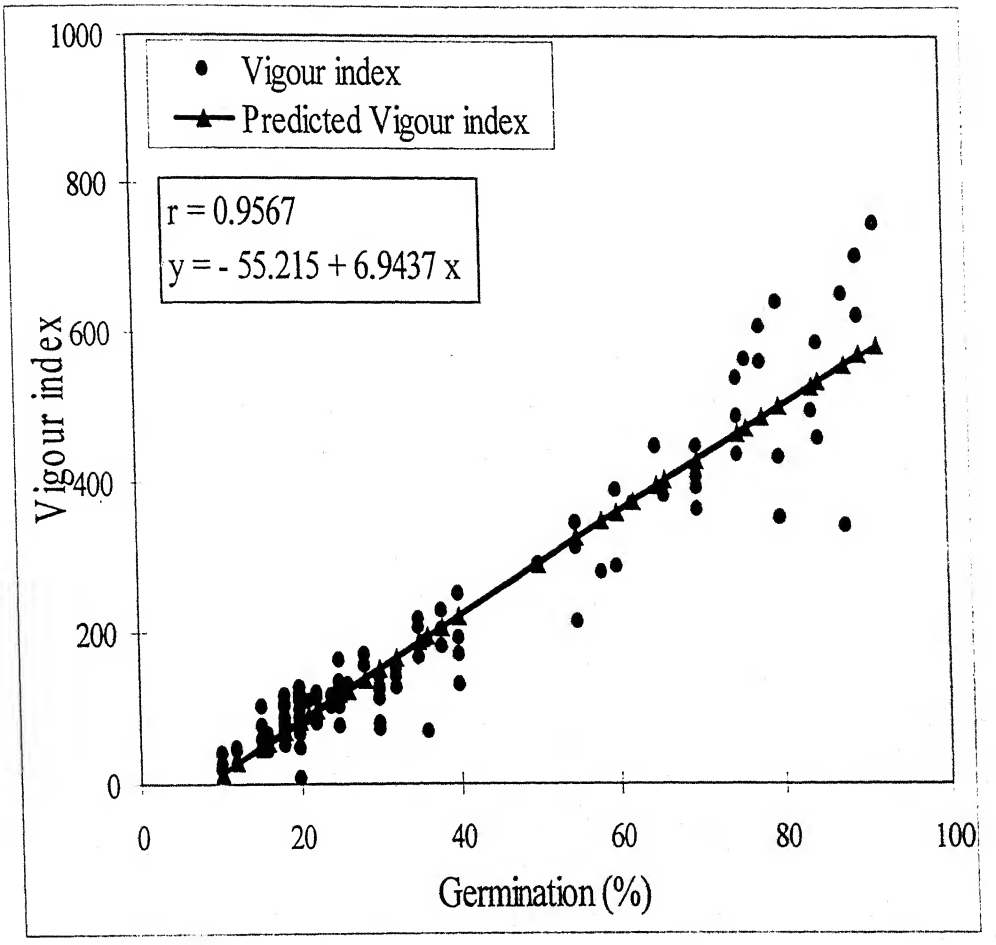


Figure 35. Relationship between vigour index and germination (%) in different genotypes of *Stylosanthes*.

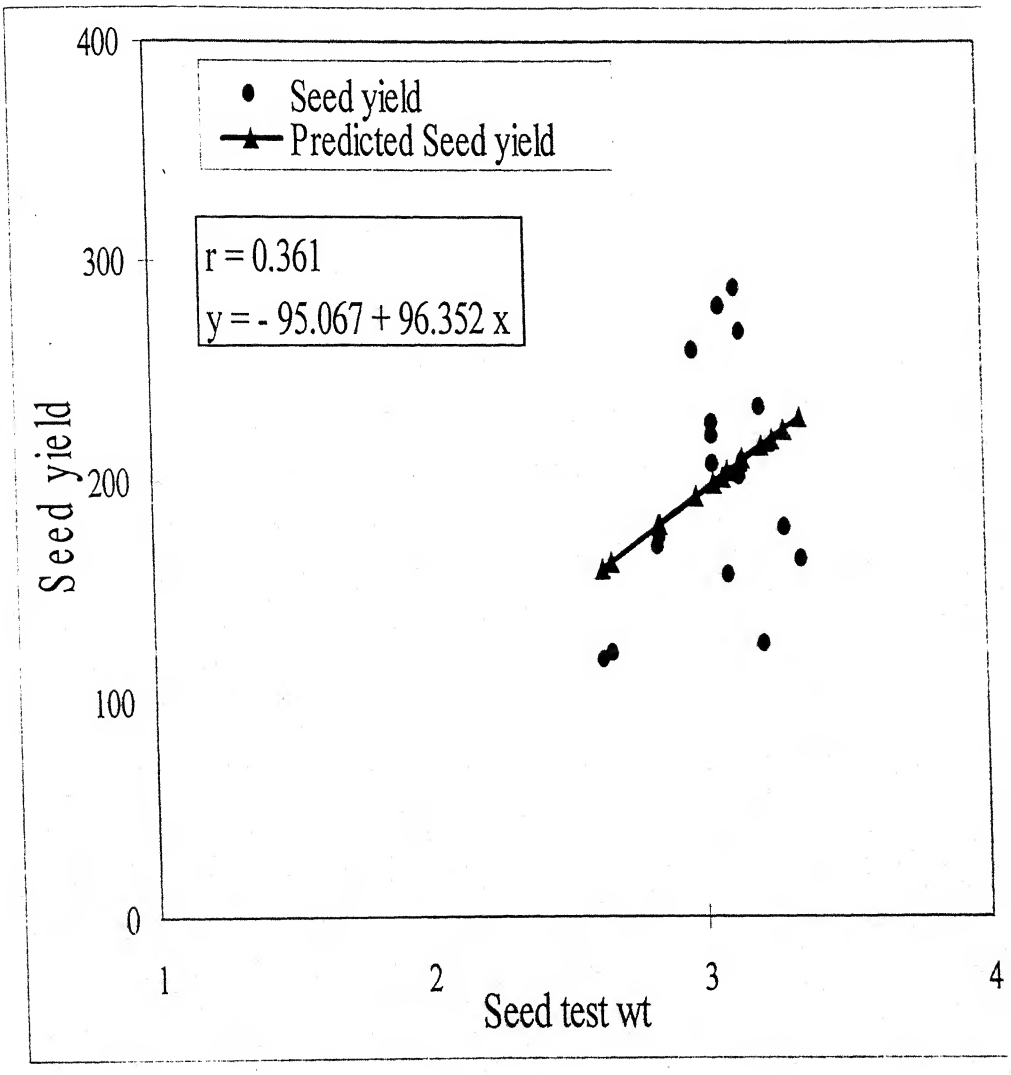


Figure 36. Relationship between seed yield and seed test weight in *Stylosanthes genotypes*

therefore, recommended the most economical and practical method for getting better field establishment in *Stylosanthes*. Although hot water treatment also improves the seed germination and similar to our results (Rai 1984) has also reported that hot water treatments for 90 seconds improve the germination in *Stylosanthes*.

Maximum germination was recorded (92%) in *S. seabrana* (104710) and (55%) in *S. viscosa* under the scarification treatment. On average of all the treatments the maximum seedling length was recorded under scarification treatment and the variation ranged from 3.9 cm to 8.10 cm whereas, under the control (without any treatment) the various seedling growth ranged from 1.8 cm to 6.10 cm. The variability among the genotypes of different species of *Stylosanthes* was also indicated by the vigour index traits. On average of all the treatments the highest vigour index was recorded in *S. seabrana* (104710) followed by *S. scabra* (105546 B) and minimum in *S. viscosa*.

Seed test weight has got the direct relationship with the seed germination and seed vigour index. Indicated the fact that the seeds having higher seed test weight accumulated more photosanthes and translocates the energy for better seed germination and therefore, seed vigour index improves. The total seedling length was also improved by the application of these dormancy breaking seed treatments and it has been observed that the maximum seedling elongation was achieved through seed scarification treatment followed by $H_2SO_4$. Similar to the better seed germination, seedling elongation and vigour index were also improved by the dormancy breaking seed treatments of scarification through course sand paper and conc. $H_2SO_4$ (5 minute) and therefore, these treatments were recommended as the suitable dormancy breaking treatments for better germination and field establishment

The data of germination, seedling elongation, vigour index and seed weight were correlated with each other and it has been observed that the germination is positively and significantly correlated with vigour index (r=0.7648). The liner

relationship of germination with vigour index is presented in figure 40 and data revealed the positive and liner relationship among these parameters which, indicates that in the better germinated seed the vigour index is also of high value.

## II- Effect of foliar applied growth hormone on growth, assimilatory characters and seed yield in *S. hamata.*

The effect of foliar applied growth hormone ($GA_3$, 100 ppm, NAA 100 ppm), growth retardant (Cycocel 0.5 kg/ha) and nutrient ($KNO_3$ 4kg/ha and Boron 100ppm) on plant growth, physiology, biomass production and seed yield were studied under field condition over consequetive years in *Stylosanthes hamata*. The treatments were imposed at vegetative and flowering initiation stage of the crop growth. The shoot growth in term of plant height was increased by the use of foliar application of growth homone and nutrients being maximum by the application of NAA 100 ppm whereas it decreased by 13% by the foliar application of cycocel (0.5 kg/ha). Increase in plant height with the application of NAA (100 ppm) was also reported (Mehrotra, 1983) in wheat. The cell division and cell elongation might be influenced by this chemical (Little and Laoch 1975). Effect of NAA on cell division and elongation in the presence of endogenous gibbralic acid (Brain and Hemming 1958) might have resulted increased plant height. The application of NAA (100ppm) was more effective because NAA stimulate cell growth in the meristem (Martins 1977). The increment in shoot growth occurred due to enhancement of photosynthetic activity which ultimately increases the photosynthate accumulation and its partitioning towards the shoot growth as evidenced from the positive and significant co-relation of shoot growth with PN ($r= 0.6257$) (Table 31). It is evident from observations that the number of branches per plant significantly increased by the foliar application of these chemicals. The application of NAA and $GA_3$ were more effective. The branch production may be increased either due to the effect of growth hormone on cell division (Paul *et. al.*, 1975; Yadav and Shrinath 1975) or more accumulation of biomass and its partitioning to branch formation.

Table 31. Correlation coefficient among various characters as influences by the foliar application of growth hormones and nutrients.

| | Plant height | Branch no. | Flower no | Seed yield | Seed test wt | Leaf temp. | PN | TR | CINT | CS | PN/ CINT | PN/TR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Plant height | 1.0000 | | | | | | | | | | | |
| Branch. no. | 0.4808 | 1.0000 | | | | | | | | | | |
| Flower no. | 0.4135 | 0.8057 | 1.0000 | | | | | | | | | |
| Seed yield | 0.4807 | 0.8534 | 0.9663 | 1.0000 | | | | | | | | |
| Seed test wt | 0.5453 | 0.8371 | 0.8313 | 0.9252 | 1.0000 | | | | | | | |
| Leaf temp. | -0.1334 | 0.7792 | 0.4804 | 0.5026 | 0.4599 | 1.0000 | | | | | | |
| PN | 0.6257 | 0.0257 | 0.2825 | 0.2464 | 0.3654 | -0.5096 | 1.0000 | | | | | |
| TR | 0.1839 | 0.3919 | -0.0648 | 0.0777 | 0.4098 | 0.3933 | 0.0857 | 1.0000 | | | | |
| CINT | -0.4945 | -0.4605 | -0.0407 | -0.1238 | -0.0810 | -0.3535 | 0.3323 | -0.1540 | 1.0000 | | | |
| CS | 0.4330 | 0.1124 | -0.0473 | -0.1715 | -0.1610 | -0.0664 | 0.3749 | 0.1294 | -0.3441 | 1.0000 | | |
| PN/ CINT | 0.8620 | 0.1988 | 0.2729 | 0.2279 | 0.2675 | -0.3750 | 0.8255 | 0.0248 | -0.2103 | 0.7053 | 1.0000 | |
| PN/ TR | 0.0522 | -0.4125 | 0.1599 | -0.0077 | -0.1993 | -0.6474 | 0.5292 | -0.7688 | 0.5151 | 0.0991 | 0.3841 | 1.0000 |

CRITICAL VALUE (1-TAIL, .05) = + Or - .37911
CRITICAL VALUE (2-tail, .05) = +/- .44260

The microenvironmental parameters relative humidity (RH), air temperature (AT) and photosynthetically active radiation (PAR) were also measured at the time of taking the observations on assimilatory function of the leaves. These microenvironmental parameters indicate that all the observations pertaining to assimilatory processes and physiological activity were taken at optimum conditions under all the treatments. The effect of different chemicals as applied on leaves has not shown any remarkable change in leaf temperature. This clearly indicates that these chemicals have not changed the microenvironment surrounding of the leaf and therefore, the leaf remain physiologically active. Takeing into consideration the assimilatory functions of *Stylosanthes hamata* as influenced by foliar application of different concentration of NAA, $GA_3$, $KNO_3$ Boron and Cycocel resulting that the rate of photosynthesis increased by the application of these chemicals. The results revealed that foliar application of $GA_3$ (100ppm) and NAA (100 ppm) played significant role in enhancing the rate of $CO_2$ assimilation and through which the over all photosynthetic rate increased. The photosynthetic rate is associated with other morphophysiological character as evidenced by positive co-relation of PN with stomatal conductance (r= 0.3749), carboxylation efficiency (PN/CINT), (r= 0.8255) and water use efficiency (PN/TR), (r= 0.5292) (Table 31).

The process of transpiration has not shown any definite trend by the foliar application of these chemicals. This has indicated that the foliar application of these chemicals on leaf surface has differently influenced the stomatal functioning. $GA_3$ (100 ppm) and NAA (100 ppm) treatments increased photosynthesis in S. hamata. However, Sah and Patel, (2004) reported that NAA and CCC treatments increased photosynthesis as well as transpiration rate over the control. Similar to the rate of photosynthesis the stomatal conductance increased with the application of these chemicals over the control and maximum stomatal conductance was recorded in the leaves applied with NAA (100ppm). The stomatal conductance is positively corelated with plant height, branch production indicating the fact that due to higher stomatal conductance the rate of photosynthesis increased which intern higher productivity of the plant. The foliar application of these chemicals

has differently influenced the inter-cellular $CO_2$ concentration and there by influenced the $CO_2$ assimilation, photosynthate production and its translocation. The carboxylation efficiency (a ratio of PN and CINT, PN/CINT) (Farquhar and Sharkey 1982) was heighest in the plants treated with NAA (100 ppm). Over all the foliar application of these chemicals has significant effect on carboxylation efficiency. The assimilation of $CO_2$ is intimately associated with the loss of water from leaves to the atmosphere. The photosynthesis/transpiration (PN/TR) which represent the water use efficiency (the unit as $CO_2$ fixed per unit as water loss) was maximum in the plants treated with these chemicals.

Plant growth regulators are known to regulate flowering, fruit setting and fruit development application of $GA_3$. $GA_3$ promoted or induced flower initiation in many long day plants. (Metzger, 1990). In this investigation it was observed that the flower production per plant increased significantly by the foliar application of these chemicals. The maximum flowering was induced by the foliar application of $GA_3$ (100ppm) where as the application of NAA (100 ppm) $KNO_3$ (4kg/ha) and Boron (100 ppm) were at par. The minimum numbers of flowers were induced by the foliar application of growth retardent (Cycocel 0.5 kg/ha) although it was higher than the control (untreated plants). The synchronization of the flowering were also occurred by the foliar application of these growth hormones and retardent. The seed yield in *Stylosanthes hamata* increased significantly by the foliar application of these chemicals. Maximum seed production has occurred by the foliar application of $GA_3$ (100 ppm) followed by $KNO_3$ (4 kg/ha). On average of both the years the seed yield increased by 2.4% to 37% over the control (169.7 kg/ha) by the foliar application of these chemicals as applied at vegetative and flowering initiation stage of plant growth. The increase in seed yield might be due to increase in the number of flowers per plant as indicated by the positive and significant correlation between these two parameters (r = .9663) (Table 31). The increase in seed yield is also due to increasing branch production. The rate of photosynthesis has direct relation with the seed yield (r= 0.6530) (Figure 37) and seed test weight (Figure 38). The increase in seed production by foliar application of these chemical might have increased the sink capacity and the

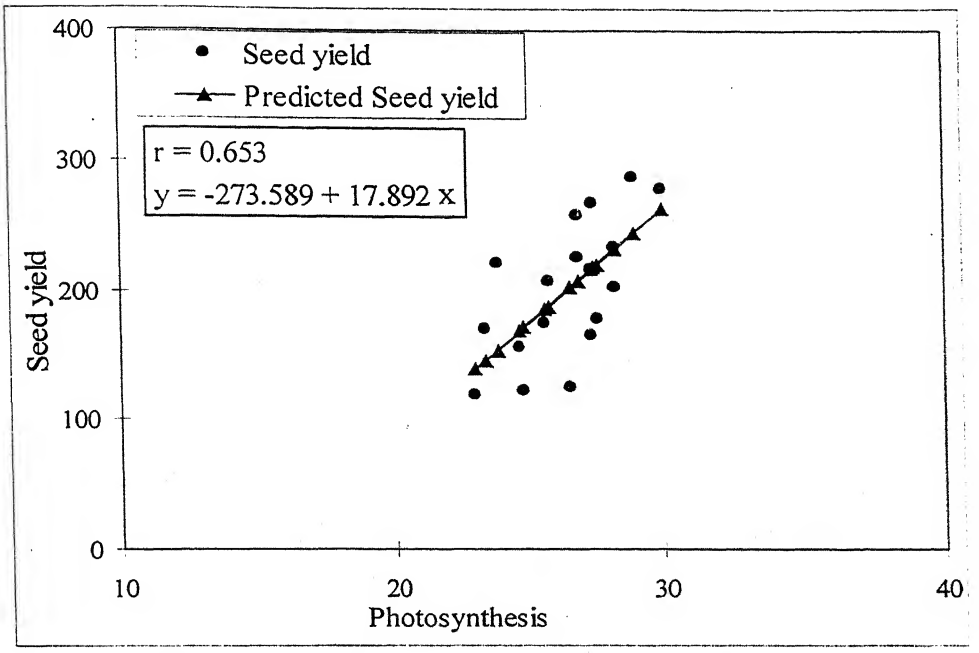


Figure 37. Relationship between seed yield and photosynthesis in *S. hamata* under various treatments.

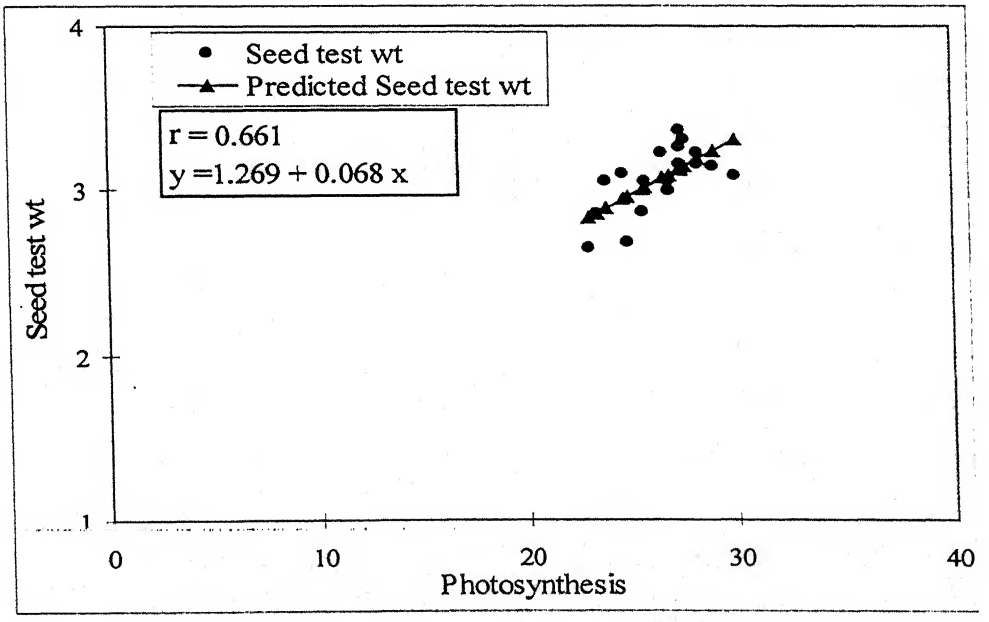


Figure 38. Relationship between seed test weight and photosynthesis in *S. hamata* under various treatments.

improvement in source sink relation through which this translocation of sugar to the sink has enhanced. Leonard *et. al.*, (1983) has reported that the growth hormone might have improved higher cell division activity which affect photosynthetic to sink organ at early stage of development. The application of potassium nitrate act as activator for translocation of sugar to the sink organ. The stimulation of vegetative growth by the application of these chemicals at vegetative stage of crop growth resulted better seed setting which finally increased the seed yield. This increase in seed yield was also directly associated with the increase in thousand seed weight as evidence by the lenear relationship of seed yield with thousand seed weight (figure 39). The results exhibited that the seed test weight (thousand seed weight), which indicate the quality of seed, significantly improved by the application of the chemicals over the control. The seed test weight was positively associated with plant height, branch number, flower number, rate of photosynthesis and transpiration as evidenced by positive and significant co-relation among these parameter Table 31.

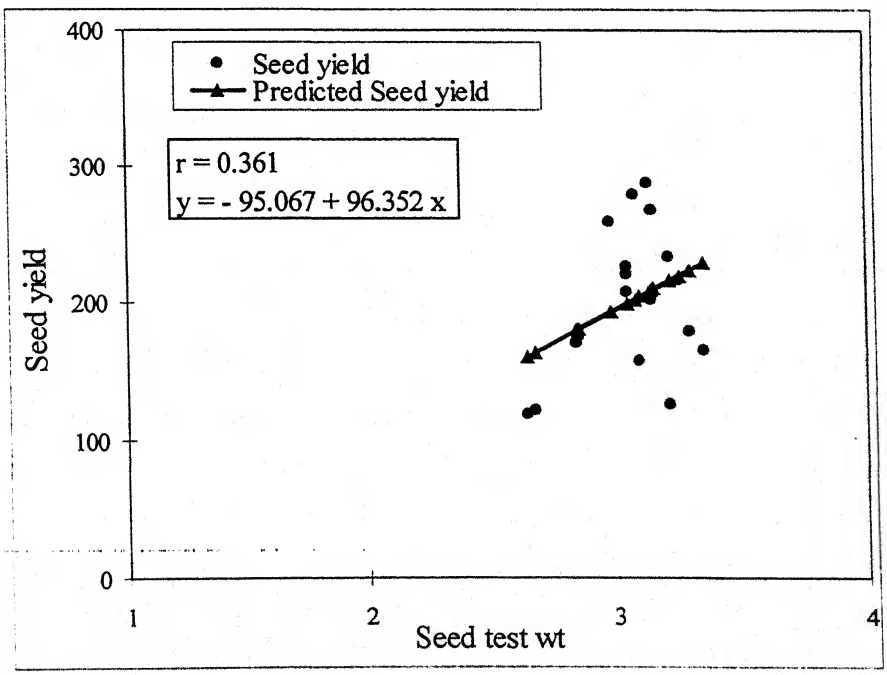


Figure 39. Relationship between seed yield and seed test weight in *S. hamata* under various treatments.

The foliar application of these chemicals as applied in flowering initiation stage remains more active to build up sufficient food reserve for maintaining the quality of seeds. Midan *et. al.*, (1986) also reported increase in seed yield with the application of auxin. It is assumed that foliar application of these chemicals at vegetative stage leads to more accumulation of biomass in leaf and stem while chemicals sprayed at flowering initiation stage partitioned more photosynthate to the reproductive part which enhanced higher seed yield. The efficiency of growth regulation in modifying the accumulation of various reserve materials during seed developments has been reported by the Crouch and Sussex (1981) and Malik *et. al.*, (1987). The superiority of foliar nutrition might be due to the requirements of nutrients at peak period of flowering and seed development. The quality of nutrients absorbed by roots at peak period of nutrient requirement may not be sufficient to meet the needs at seed development stage. Supplementing nutrient through foliage might have resulted in better nutrition balance in the plant leading to increased yield components. Similar resulted were also observed by Reddy *et. al.*, (1991). The increase in seed yield has also been reported with various growth regulation in several pulse crops (Setia *et. al.*, 1988, 1989). Naidu *et. al.*, (2003) reported that the combination of auxin treatment and azospirillum inoculation resulted in to enhance maintain yield contributing character leading to higher yield.

From the present investigation it can be concluded that foliar application of growth hormone and nutrients are more beneficial for seed yield improvement in *Stylosanthes hamata*. The foliar application of growth hormone reduced the flower drop as also reported by Lakshmamma and Crowd (1996). It has been reported by various worker that plant growth regulators modified the growth and development pattern by influencing various physiological process and hance regulating the productivity (Brenner, 1987, Clifford *et. al.*, 1986, Patrick, 1988, Setia *et. al.*, 1991).

The increase in seed yield per plant might be due to increasing pod formation by the application of these chemicals. The NAA act as activator and stimulate the efficiency of developing sink to reserve more assimilate where as

$GA_3$ in the flowering hormone act as inducing more flowering buds also intern more seed formation resulted higher seed yield. Application of $KNO_3$ has produced more metabolites and Photosynthates and the available potassium (K) act as activator for transport of metabolites towards sink resulting in increasing seed yield. Applied potassium improved yield parameters which was assigned to influence certain physiological processes like symbiotic $N_2$ fixation, photosynthesis and carbohydrates translocation for sink growth (Patra *et. al.*, 1995).

The foliar spray of these chemicals might have maintained more chlorophyll accumulation and soluble protein therefore, delay in senescence through which over all assimilation enhanced and finally the seed yield increased. The foliar application of different agrochemical maintained the longer leaf area duration and reduced the senescence rate considerable, which in turn the photosynthetic activity continued for longer period. The result revealed that yield contributing character and physiological attributes could be effectively altered by foliar replication of growth regulators to achieve higher yield potential. Therefore, it is clear from this investigation that foliar application of growth hormone and nutrients positively influenced the morphophysiological parameter, assimilatory functions and bio-chemicals attributes for increasing the quality seed yield in *Stylosanthes hamata.*

# 6

# Summary

The present investigation entitled ***"Physiological Analysis for Biomass Production and Seed Yield in Stylo"*** was carried out at experimental field of Central Research Farm of Indian Grassland and Fodder Research Institute, Jhansi (U.P.) India (latitude $25.27^0$ N, longitude. $75.35^0$ E and an altitude of 275 meters above sea level) during the years 2002 and 2003. For this study the promising genotypes of *Stylosanthes* belonging to *S. hamata*, *S. scabra, S. seabrana* and *S. viscosa* were selected because of they were introduced for the first time from Australia. In this study the following experiment were conducted:

1. Growth, morphophysiological characters, seed yield and germination of different genotypes of *Stylosanthes* (viz. *S. hamata* 110123, *S. hamata* 110135, *S. hamata* 61670, *S. scabra* 36260, *S. scabra* 93116, *S. scabra* cv. *Fitzroy, S. scabra* cv. Seca, *S. scabra* q 10042, *S. scabra*RRR 94-100, *S. scabra* RRR 94-86, *S. scabra* RRR 94-93, *S. scabra* RRR 94-97, *S. scabra*

RRR 94-96, *S. seabrana* 104710, *S. seabrana* 105546 B, *S. seabrana* 110372, *S. seabrana* 2523, *S. seabrana* 2534, *S. seabrana* 2539, *S. viscose*).

2. Effect of foliar applied growth hormone [($GA_3$ (100 ppm), NAA (100 ppm)], nutrients [($KNO_3$ (4 kg/ha) and Boron (100 ppm)] and growth retardant (Cycocel 0.5 kg/ha) on flowering, seed setting, seed yield and quality of seeds in *Stylosanthes hamata.*

This investigation was undertaken with the following objectives:

1. To study the growth behaviour, morphophysiological characters, biomass production and seed production potential.
2. To assess the effect of foliar applied growth hormone and nutrients on flowering, seed setting, seed yield and quality of seeds in *Stylosanthes.*
3. To assess the influence of these chemicals on assimilatory functions, photosynthetic pigments, nitrate reductase activity, protein and sugar accumulation.

The salient findings are as under:

1. On the basis of growth performance *S. scabra* cv. *seca* attained the maximum height followed by *S. seabrana* 110372 and minimum plant height was recorded in *S. hamata* 110135. However, maximum root length was recorded in *S. seabrana* 110372 and minimum in *S. hamata* 110135. The genotypic variability in diameter growth was narrow in case of different genotypes of *S. scabra* and *S. seabrana.*

2. The leaf length varied from 1.95 cm (*S. viscosa*) to 3.10 cm in (*S. hamata* 110123). Similarly the variation in leaf width ranged from 0.5 cm. (*S. hamata* 110135) to 1.20 cm (*S. scabra* RRR 94-97). The genotypic variability in leaf width was higher as compared to the leaf length.

3. Maximum fresh biomass and dry biomass production was observed in *S. scabra* RRR 94-100 followed by *S. scabra* q 10042 and minimum in *S. hamata* 110123. Large variability exists in the *Stylosanthes* germplasm.with respect to their biomass production potential. The total biomass production during the second year was much higher than the first year, which may be due to the regeneration of the first year harvested plants in the second year.

4. The leaf area ranged from 2.220 $cm^2$ (*S seabrana* 2523) to 3.873 $cm^2$ (*S. scabra* q 10042). The specific leaf weight (SLW), which represents the accumulations of dry matter in per unit leaf area ranged from 4.86 $mg/cm^2$ to 9.44 $mg/cm^2$. Maximum specific leaf weight was recorded in *S. scabra* RRR 94-100, followed by *S. scabra* q 10042, *S. sesbrana* 2539 and lowest SLW was observed in *S. hamata* 110123.

5. The rate of photosynthesis in different genotypes ranged from 19.65 μ mole/$m^2$/s to 27.67 μ mole/$m^2$/s. Maximum rate of photosynthesis was recorded in *S. scabra* cv seca (27.67 μ mole /$m^2$/s) followed by *S. scabra* RRR 94-93 (26.12 μ mole/$m^2$/s) and minimum in *S. hamata* 110135 (19.65μ mole/$m^2$/s).

6. The transpiration rate ranged from 8.40 m mole/$m^2$/s to 13.33 m mole/$m^2$/s. Maximum rate of transpiration was recorded *S. scabra* RRR 94-93 followed

by *S. seabrana* 110372 which were at par to *S. scabra* 93116 and minimum in *S. hamata* (Diploid) 61670. Genotypic variability in the rate of transpiration was maximum in the genotypes of *S. scabra* as compared to the *S. seabrana* genotypes.

7. The stomatal conductance ranged from 0.58 (sec/cm) to 1.12 (sec/cm) being maximum in *S. scabra* 2534 followed by S. scabra CV seca and minimum in *S. hamata* 110135 and *S. scabra* cv q 10042 which was at par to *S. hamata* diploid (61670).

8. The higher intercellular $CO_2$ concentration was recorded in *S. hamata* 110123 (239.25 ppm) followed by *S. seabrana* 105546 B (233.10 ppm) and lowest in *S. scabra* RRR 94-100 (187.61 ppm).

9. Maximum carboxylation efficiency was recorded in *S. scabra* cv seca followed by *S. scabra* RRR 94-100 and *S. seabrana* 2534 and minimum in *S. hamata* 100135. The ratio between photosynthesis and transpiration, which indicate water use efficiency, was found to be highest in *S. scabra* (RRR 94-100) and minimum in *S. scabra* (93116).

10. In general all the genotypes accumulated higher chlorophyll a as compared to chl b. The accumulation of chlorophyll a ranged from 0.58 mg/gm fresh weight (*S. scabra* RRR 94-97) to 1.30 mg/gm (*S. seabrana* 104710) whereas chlorophyll b ranged from 0.19 mg/gm (*S. scabra* RRR 94-96) to 0.38 mg/gm fresh weight (*S. scabrena* 104710).

11. Maximum NR activity was estimated in *S. viscosa* followed by *S. hamata* and *S. seabrana* and minimum NR activity was observed in the genotypes of *S.*

*scabra*. The data revealed that there is large variability among the species while among the genotypes with in the same species the variability is very low.

12. Higher accumulation of water soluble sugar in leaves was estimated in *S. scabra* cv. seca (33.93 mg $g^{-1}$ dry wt) followed by *S. seabrana* 104710 (31.33 mg $g^{-1}$ dry wt) and minimum in *S. hamata* (diploid) 61670 (10.71 mg $g^{-1}$ dry wt).

13. The variation in crude protein content in different genotype ranged from 13.91 % to 18.26 %. The crude protein accumulation in all the genotypes of *S. hamata* was higher followed by *S. viscosa* where as the genotypes of *S. scabra* and *S. seabrana* were at par.

14. In all the genotypes the flowering started in the first and second week of September in the first year whereas during the second year the flowering initiation was observed in second week of August in some genotypes and first week of September in other genotypes. All the genotypes attended 50% flowering in the month of October and November and completed in November, December and January according to flowering initiation. In general the flowering period of genotypes ranged from 67 days to 130 days.

15. Genotypic variation in seed yield was observed. Maximum seed yield was recorded in *S. seabrana* 2534 followed by *S. seabrana* 2523 and minimum in *S. hamata* diploid 61670. The genotypes of *S. seabrana* were high seed yielder followed by the accessions of *S. scabra* where as the genotypes the *S.*

*hamata* were lower seed yielder. It is observed that there is large variability in the yield characters among the genotypes of *Stylosanthes.*

16. Thousand seeds weight which represent the seed test weight ranged from 2.69 gm (*S. scabra* 36260) to 3.55 gm (*S. scabra* RRR 94-93). No definite trend was observed in the seed test weight among the genotypes of *S. hamata, S. scabra* and *S. seabrana.* However, most of the genotypes were at par in their seed test weight.

17. Maximum germination (79%) was recorded in the seeds scarified through sand paper followed by concentrate $H_2SO_4$ (5 minutes) treatment (56%) and minimum germination was observed in the control (19%). The effect of $GA_3$ (300 ppm), $KNO_3$ (0.2 %) and hot water (60 °C) treatments were at par with respect to germination. Comparing the genotypic difference maximum germination was recorded in *S. seabrana* (104710) followed by *S. seabrana* 2523, *S. scabra* 93116, *S. hamata* 110123 and *S. seabrana* 105546 B in the scarification treatment and minimum germination was recorded in *S. viscosa.* The germination of seeds has also improved to double, triple and fourth folds by the treatment of $H_2SO_4$. The result revealed that the germination percentage in different genotype of *Stylosanthes* could be improved by the scarification of seeds.

18. The highest value of vigour index was recorded it the scarification treatments and lowest in control. The maximum vigour index was observed in the seedlings of *S. seabrana* followed by *S. scabra* and *S. hamata* where as lowest value of vigour index was observed in *S. viscosa.*

19. The foliar applied growth hormone $GA_3$ (100 ppm), NAA (100 ppm), nutrients $KNO_3$ (4 kg/ha) and Boron (100 ppm) and growth retardant (Cycocel 0.5 kg/ha) has sown remarkable effect on plant height in *S. hamata*. Maximum plant height was induced by the treatment of NAA (100 ppm) and minimum in cycocel (0.5 kg/ha). The response of $GA_3$ (100 ppm), $KNO_3$ (4 kg/ha) and Boron (100 ppm ) were at par to the control. The response of growth hormone on branching was more effective.

20. The rate of photosynthesis increased significantly by the foliar spray of chemicals over the control. Maximum rate of photosynthesis was recorded in the plants treated with $GA_3$ (100 ppm) and NAA (100 ppm) followed by $KNO_3$ (4 kg/ha) where as the response of Boron (100 ppm) and cycocel (0.5 kg/ha) were at par.

21. No definite trend was observed with respect to the foliar application of growth hormones, nutrients and growth retardant over the control but maximum rate of transpiration was recorded in the plants sprayed with NAA (100 ppm) followed by $KNO_3$ (4 kg/ha).

22. The stomatal conductance increased by the foliar application of chemicals over the control in NAA (100 ppm) treated plant where as it was at par in the $GA_3$ (100 ppm), $KNO_3$ (4 kg/ha) Boron (100 ppm ) and Cycocel (0.5 kg/ha) treatments.

23. The carboxylation efficiency was found to be maximum in plants treated with growth hormones, nutrients and growth retardant. The water use efficiency

was found to be maximum in the plants treated with $GA_3$ (100 ppm) and minimum in control.

24. The flower production increased significant by the foliar application of growth hormones and nutrients over the control. Maximum number of flowers were recorded in the plants treated with $GA_3$ (100 ppm) where as the response of NAA (100 pm), $KNO_3$ (4 kg/ha) and Boron (100 ppm) was at par. Flower production and synchronization of flowering were significantly improved by the application of these chemical over the control.

25. The seed yield of *S. hamata* was significantly increased by the foliar application of growth hormones, nutrients and growth retardants. Over all seed yield increased by 2.4% to 37% over the control (169.70 kg/ha) by the foliar application of these chemical as applied at vegetative and flowering initiation stage of the plant growth.

26. The seed quality in term of seed test weight was also improved by the foliar application of these chemicals, over the control. On average of both the years the seed test weight ranged from 2.85 gm (control) to 3.26 gm ($KNO_3$, 4 kg/ha).

From the present investigation it is recommended that the genotypes of *S. scabra* RRR 94-100 and q 10042 and *S. seaberna* 2534 has been selected as high biomass producing genotypes whereas *S. scabra* cv seca and *S. scabra* RRR 94-93 and *S. seaberna* 2534 as photosynthetically efficient genotypes. As evident from the data the genotypes of *S. seabrana* were high seed yielder as compared to the genotypes of *S. scabra* and *S. hamata* under semi arid environmental condition.

These genotypes should be incorporated in the stylo improvement programme. Scarification seed treatments for dormancy breaking in different genotypes of *Stylosanthes* is the easiest and feasible method and therefore, recommended the most economical and practical method for getting better field establishment in *Stylosanthes*. Similar to the better seed germination and seed vigour index was also improved by use of conc. $H_2SO_4$ (5 minutes) and therefore, this treatments is also recommended as the suitable dormancy breaking treatments for better germination in *Stylosanthes*.

The foliar spray of growth hormone [($GA_3$ (100 ppm), NAA (100 ppm)], nutrients [($KNO_3$ (4 kg/ha) and Boron (100 ppm)] and growth retardant (Cycocel 0.5 kg/ha) in *Stylosanthes hamata* might have maintained more chlorophyll accumulation and soluble protein therefore, delay in senescence through which over all assimilation enhanced and finally the seed yield increased. The result revealed that yield contributing character and physiological attributes could be effectively altered by foliar replication of growth regulators to achieve higher yield potential. Therefore, it is clear from this investigation that foliar application of $GA_3$ (100 ppm) and $KNO_3$ (4 kg/ha) at vegetative and flowering initiation stage positively influenced the morphophysiological parameter, assimilatory functions and bio-chemicals attributes for increasing the quality seed yield in *Stylosanthes hamata*.

The recommendation given in this investigation will be used as package of practices to enhance the biomass and seed production in *Stylosanthes*. The information gathered in this investigation would definitely be helpful to the researchers, planers development workers and seed growers.

# 7

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